Navy Personnel Research and Development Center

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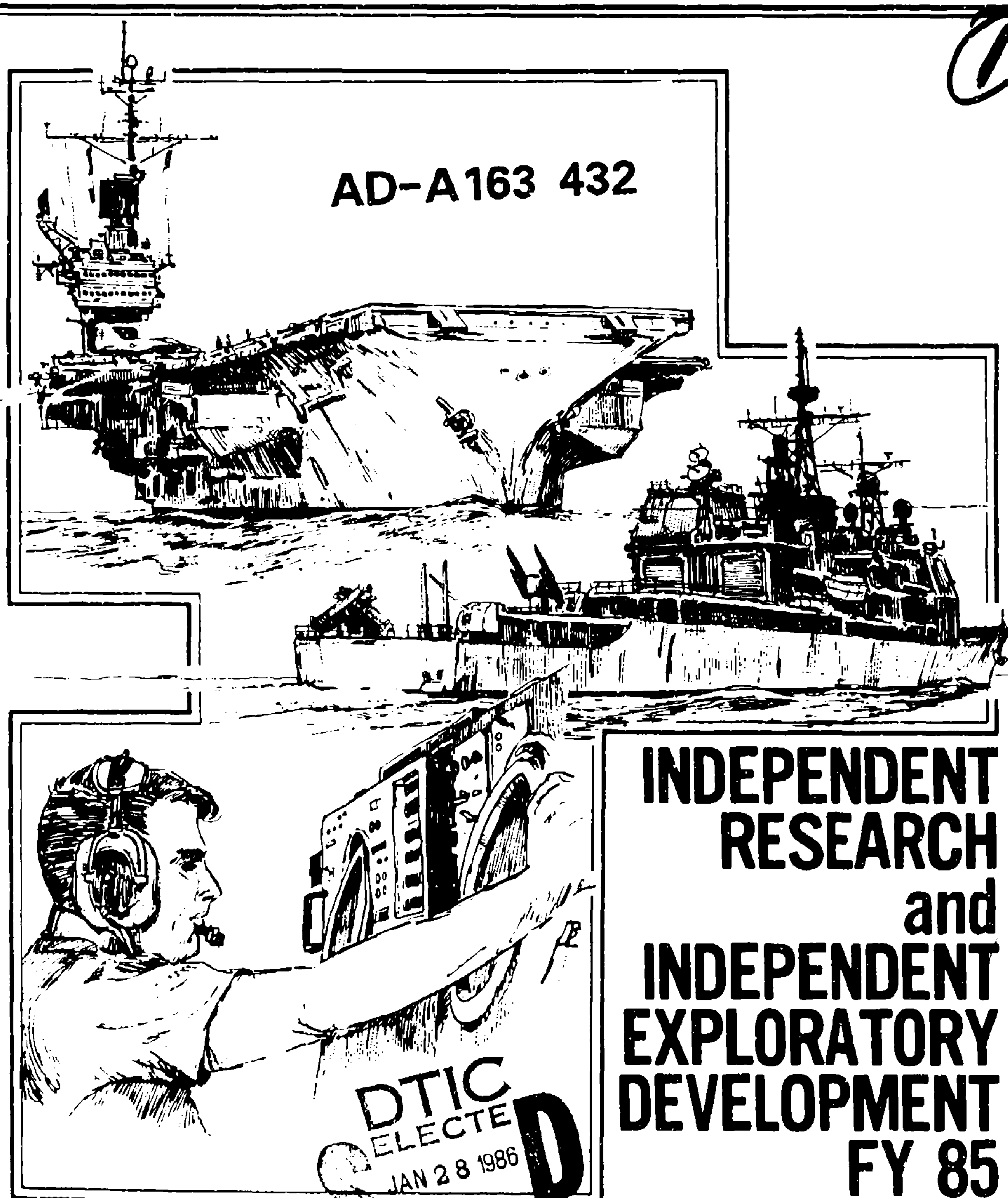

INDEPENDENT RESEARCH and INDEPENDENT EXPLORATORY DEVELOPMENT FY 85

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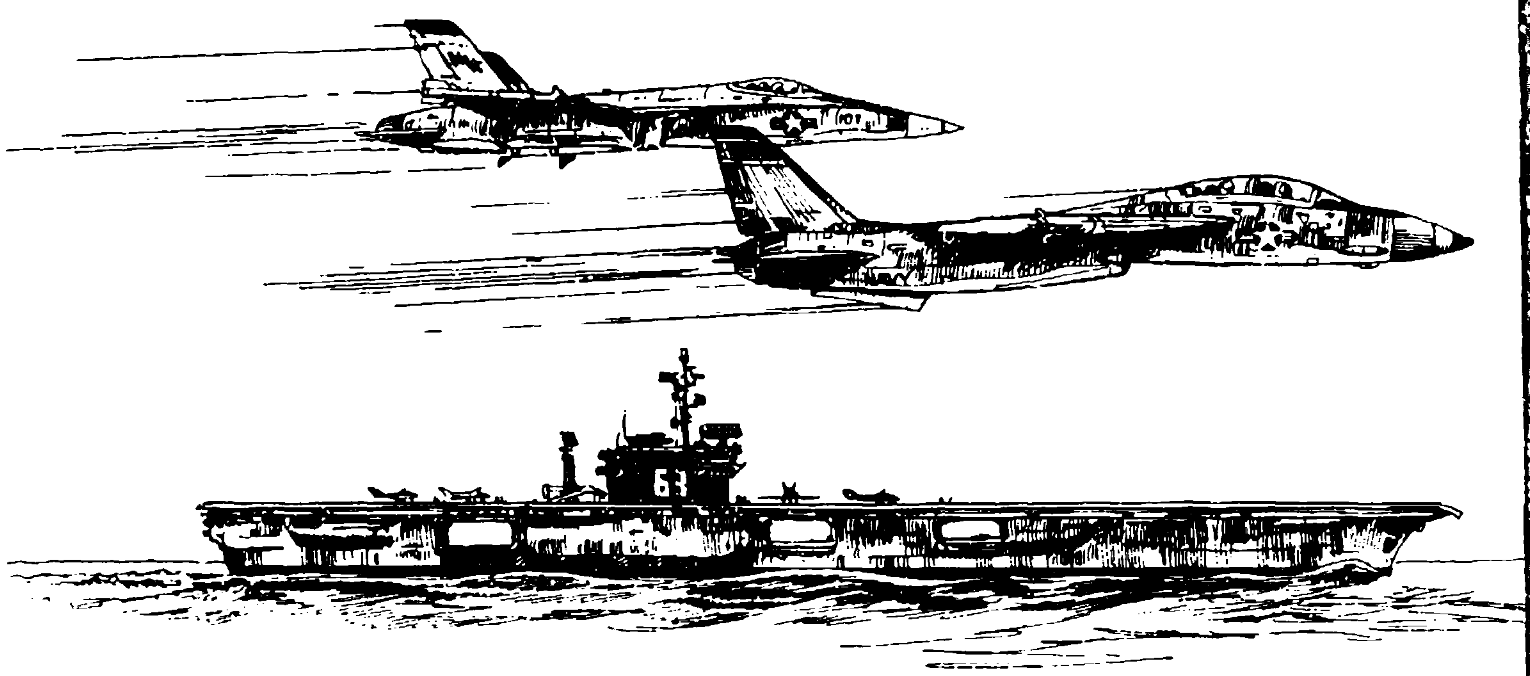

FOREWORD

The technical directors of Navy Laboratories receive Independent Research (IR) and Independent Exploratory Development (IED) funding annually to support innovative, promising work without going through the formal approval procedures required under normal funding authorization. This funding enables the researchers selected for the program to devote a portion of their time to basic research that offers potential benefits for specific military problem areas.

Research at the Navy Personnel Research and Development Center addresses the Navy's needs for enhancing system and personnel performance through the integration of people and technology. Resources provided for the IR/IED program have been used to develop a variety of research methods, models, and techniques within the areas of training, manpower utilization, organizational productivity, and human factors engineering of naval weapon systems and platforms.

The IR program has been active at this Center since 1973 and is funded under Program Element (PE) 61152N. The IED program was initiated in 1976 and is funded by PE 62766N.

This report is submitted to fulfill the requirement for an annual IR/IED report. It provides summaries of selected FY85 projects, the program funding profile, a list of the honors and awards IR/IED researchers earned during FY85, and a list of FY85 publications and presentations resulting from IR/IED efforts.

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Commanding Officer

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NPRDC Special Report 86-1 January 1986

INDEPENDENT RESEARCH AND INDEPENDENT EXPLORATORY DEVELOPMENT FY85

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CONTENTS

INDEPENDENT RESEARCH PROGRAM

CONTENTS

MODELS FOR CALIBRATING MULTIPLE-CHOICE ITEMS[1]

James Bradford Sympson

Dichotomous (right/wrong) scoring of multiple-choice test questions does not distinguish among various wrong answers chosen by examinees. Wrong answers can supply valuable information about examinee ability. A new item-response model and a polychotomous item-scoring procedure were developed which have several benefits for selecting and classifying military personnel.

BACKGROUND

Mental Testing. For more than 40 years, the selection and classification of enlisted military personnel has depended heavily on objective tests of mental ability. These tests are especially appropriate for selecting and classifying individuals who lack specialized training or experience and must undergo formal training in preparation for their job assignment.

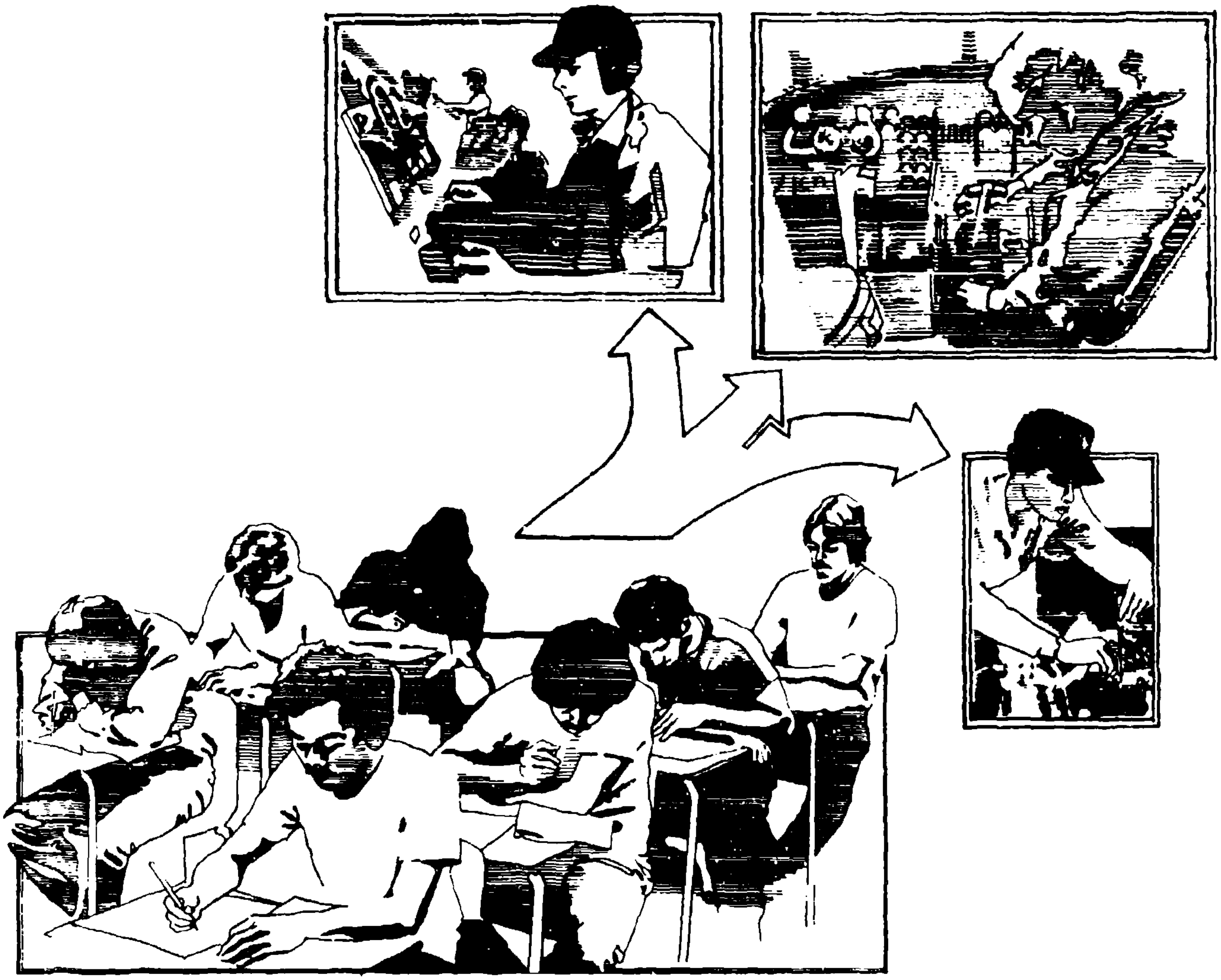
The benefits of using mental ability tests for screening and classifying military recruits go far beyond identifying individuals who are likely to perform well during their initial enlistment. Since the armed services promote from within, the quality of personnel available for the upper enlisted ranks ultimately depends on the quality of personnel accepted for initial entry. Thus, both short- and long-term outcomes rely heavily on decisions that are made at initial recruitment. Mental ability tests increase the likelihood that these decisions will be good decisions.

Multiple-choice Questions. Paper-and-pencil mental ability tests, such as the Armed Services Vocational Aptitude Battery (ASVAB), typically consist of multiple-choice questions. Even though computerized testing will probably reduce the use of paper-and-pencil tests, multiple-choice items will continue to be widely used. Even when the examinee is asked to enter a "free response" on a computer (which requires the examinee to recall rather than recognize the correct answer), the computer must assign the response to one of several predefined, mutually-exclusive categories. Thus, even test questions that are not presented in a multiple-choice format will usually be scored as if they were multiple-choice items.

PROBLEM

In current applications of multiple-choice ability testing (e.g., the ASVAB and computerized testing), examinee responses are scored as either correct or incorrect. This dichotomous item scoring procedure ignores distinctions among the various incorrect answers and loses information about examinee ability that could be extracted from the wrong answers.

[1]Cost shared with Center 6.2 funding ($20K from PE 62763N).



Mental ability tests are used as an aid for placing recruits into Navy jobs.

OBJECTIVE

The objective of this research is to develop psychological measurement (psychometric) procedures to extract information from examinees' wrong answers to test questions. In order to accomplish this, we are developing polychotomous item-response models, new testing strategies based on these models, and scoring methods that extract information about examinee ability from all item responses--incorrect as well as correct.

PROGRESS

Several polychotomous item-response models have been developed and tried on actual test data. The most promising of these models is being evaluated thoroughly. A computer program that computes response-option scoring weights has been developed and applied to several sets of test data. A new family of statistical distribution functions and a computer program that fits this distribution function to sets of test scores have also been developed.

EXAMPLE

A 25-item test of arithmetic reasoning ability taken by 1300 USMC recruits was analyzed using the option-scoring program developed in this research. Figure 1 shows the difference between dichotomous and polychotomous item scoring for the following multiple-choice item from this test:

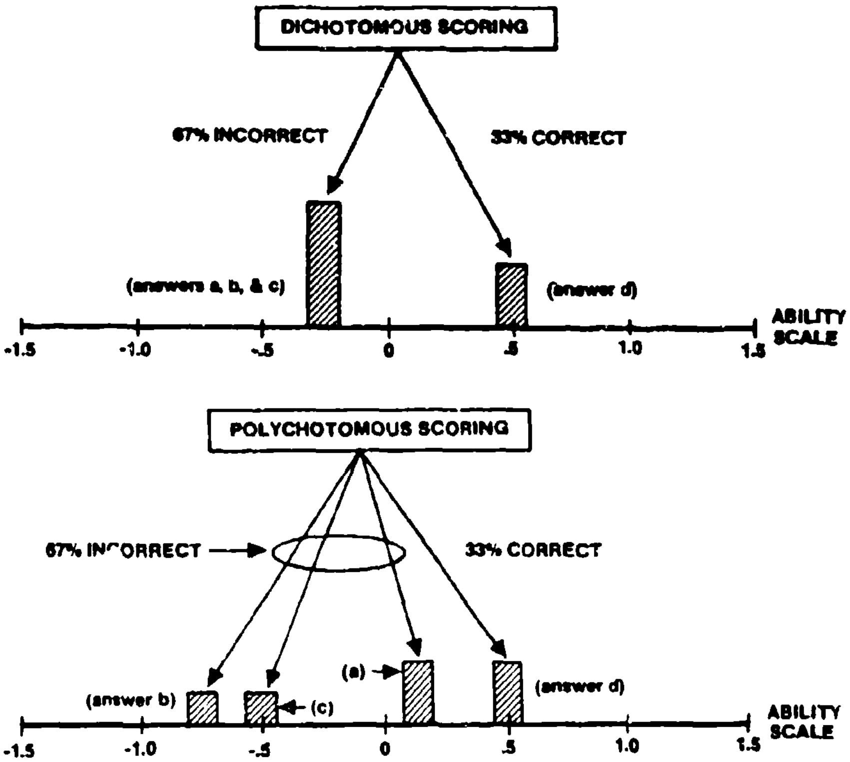
> A key rack has 8 rows of hooks. Each row has 6 hooks. If 25 percent of the hooks have keys on them, how many hooks are empty?
>
> (a) 12
> (b) 16
> (c) 32
> (d) 36 (correct answer)

Solv .ıg this problem requires three steps:

1. 8 x 6 = 48 hooks.
2. 48 x .25 = 12 hooks with keys.
3. 48 - 12 = 36 empty hooks.

Of the Marine recruits tested, 33 percent selected option "a" as the correct answer. Apparently, these individuals completed the first two steps in the solution, and then stopped. Although option "a" is incorrect, choosing this option clearly indicates a higher level of ability than does choosing either option "b" or "c," which are unrelated to the sequence of steps involved in arriving at the correct answer.

The upper portion of Figure 1 shows the result of scoring this 4-choice item dichotomously. Examinees who selected



Polychotomous scoring allows us to distinguish among people who answer incorrectly. This increases test reliability.

Figure 1. Models for calibrating multiple-choice items.

the correct answer (33%) were assigned a positive ability-level estimate, while examinees who answered incorrectly (67%) were assigned a negative ability-level estimate.

The lower portion of Figure 1 shows the result of scoring this same item polychotomously. Examinees who answered correctly were assigned the same ability estimate as before, but examinees who answered incorrectly were assigned one of three ability estimates depending on which incorrect answer they chose. In particular, examinees who selected response option "a" received a positive ability estimate that is lower than the one assigned to examinees who answered correctly. Sorting people who answer incorrectly into different groups provides additional information about their mental ability and increases test reliability.

This example demonstrates how additional information about an examinee's ability-level can be extracted by considering which incorrect answer the examinee selected. Treating all wrong answers the same can be unfair to those examinees who have given "partially correct" answers.

The importance of option "a" in this item was discovered using the psychometric procedures developed in this research. These procedures are based on statistical analyses of item responses. They do not require reading each question to discover the relationship between ability and each wrong answers.

PLANS

During FY86, we will apply our polychotomous item-response model to a variety of test questions. We will also conduct computer simulations to determine the model's applicability to computerized adaptive testing (CAT).

RESULTS

Initial results indicate that application of polychotomous item-response models will allow us to shorten mental ability tests by about 15 percent without sacrificing test reliability. Currently-used dichotomous item-response models fail to "fit" a significant portion of the multiple-choice items available, whereas our polychotomous model has fit every test item to which it was applied. Thus, more of the test questions that have been written can be used when the new polychotomous model is applied. Finally, our new procedures enable test developers to identify questions and response alternatives that are especially good or especially poor indicators of mental ability and indicate to the test developer which response alternatives should be modified to improve item performance. These benefits will improve the measurement of mental ability in military selection and classification tests.

ENHANCING UNDERSTANDING OF ELECTRIC CIRCUITS

William E. Montague

The Navy's basic electricity and electronics (BE/E) course continues to have a high attrition rate despite numerous changes in course content. Qualitative tests developed to diagnose student problems indicate that students do not understand the basic laws and concepts of electricity that they need to understand to maintain electronic devices. Current tests at BE/E school have not detected this serious learning deficiency. The results suggest changes in training materials and tests to enhance student learning. Work with the training command to improve BE/E instruction will continue.

PROBLEM

"Basic electricity" is taught as a topic in science courses or preparatory to technical courses in civilian schools and colleges, vocational programs, and military training. The Navy teaches a course in basic electricity and electronics (BE/E) to about 25,000 trainee technicians each year. Currently, the course provides the basic "core" knowledge and general test equipment skills that trainees need before they attend about 20 different follow-on courses in Navy "A" schools. The other services provide similar large-scale core training for trainee technicians. The content and sequence of topics in these courses, secondary school and college science courses, and vocational courses, are very similar. These courses teach the concepts of energy potential, circuits, resistance, current, and power, which students must understand before they can understand electronic devices and how to maintain them.

Research studies have examined the role of students' cognitive knowledge structures in learning and understanding the physical phenomena, the adequacy of students' scientific concepts, how well students explain how devices work, and why devices malfunction. Universally, students find the concepts difficult to learn and have the same types of misunderstanding during learning. Students find the physical-quantitative models difficult to generalize into an understanding of how devices work and to use this knowledge to discover reasons for malfunctioning. Emphasizing the quantitative, physical science explanations of the underlying phenomena does not seem to be an effective means for instructing.

High attrition rates have plagued the Navy's course and follow-on schools have expressed dissatisfaction with student knowledge and skills. Despite numerous attempts over the last decade to alleviate these problems by revising course materials, the attrition rates and frequency of

remediation remain about the same. This fact suggests that the reasons for the problems are more fundamental to student learning and understanding than to course materials.

The present research was undertaken to develop a means of detecting student misunderstanding and to examine ways to train more effectively. Detailed analyses of student learning difficulties should provide a basis for course revisions based on the principles most appropriate for the kinds of deficiencies revealed.

Understanding basic electricity concepts is essential for maintenance of fleet systems.

BACKGROUND

Work during FY83 and FY84 examined the BE/E course materials including teaching material and the test items. Data on the errors students made on test items were obtained to determine whether the existing tests could be used to diagnose general problems students had with the test items. The high frequency of errors students made on certain module tests and certain types of questions, coupled with other reported research, suggests that students do not understand the relationship between circuit components and functioning that the basic laws and equations of electricity describe. The course testing, however, is relatively inadequate for describing the details of student misunderstanding. Therefore, during FY85, we developed more systematic means for identifying learning difficulties and used these techniques to determine the reasons for student errors and to assess the effects of changes in training materials on student performance.

OBJECTIVES

Project goals in FY85 were to (1) identify deficits and flaws in students' solutions to test problems about simple circuits, (2) develop a summary model to describe the reasons students make these errors, and (3) test the effects of changes in instructional materials on student errors.

APPROACH

Prior to FY85, diagnostic tests had been developed to improve the means for examining student errors from which to infer student understanding of circuits. During FY85, these tests were used to evaluate changes in BE/E course materials and to test the use of an analogy in reducing errors. The diagnostic tests differ from the tests used in the current course in that they are qualitative rather than quantitative. This eliminates calculation errors, which are not directly relevant to circuit understanding and

confuse the analysis. In addition, because a student has to indicate what happens to every circuit component or measurement as a result of some change in the circuit, patterns of errors related to misconceptions (flawed or "buggy" concepts) are detectable. Analysis of these test data concentrated on replicating the error patterns Riley (1984) found in an analysis of student protocols taken while students studied the BE/E training materials and was done with her cooperation.

During FY85, test data collected from four groups of students in FY84 were analyzed to identify the students' flawed concepts. Additionally, 48 Navy BE/E students using current course materials (Coursefile 72) and 46 students using course revised materials intended to be implemented in the fall of 1985 took the diagnostic tests. Also, BE/E materials incorporating an analogy to improve the development of student understanding of circuit functioning usually described by the Ohm's Law equations were administered to five college students to clarify some issues that arose in prior research.

ACCOMPLISHMENTS

The data obtained during FY85 generally agree with those obtained from the less extensive studies run in prior years. In general, students who successfully completed the BE/E modules covering basic direct and alternating current circuits have substantial flaws in their understanding of how simple DC circuits function. Most students made multiple errors on the diagnostic tests with fewer than ten percent making no errors. Furthermore, analysis of the errors revealed considerable homogeneity in the types of errors the students made. For example, 80 percent of the errors reveal that the students misunderstand Kirchoff's Law about the distribution of voltage in circuits, which is fundamental to developing troubleshooting skills. One wonders why current tests do not detect such a gross problem and how to correct the flaws.

An analysis of the protocols taken while the students studied materials containing the analogy designed specifically to assist comprehension of circuit function provides some ideas that might help. This analogy (Riley, 1984) represents a voltage as a stack of chips or tokens and resistors, as boxes divided into slots representing resistance. In a series circuit, the chips are distributed equally to all slots. The number of tokens per slot represents current. This model provides a concrete representation of the relationships summarized by Ohm's and Kirchoff's Laws. It is easy for students to understand, requires no manipulation of abstract equations, and seems to aid student performance during learning. Students using this analogy made fewer errors than did students using the standard course materials. These results suggest that training can be improved by providing readily understood models that make circuit functioning apparent.

The analysis of the data from the two student groups (48 and 46 respectively) is not yet complete. The group using the revised materials performed slightly better on one of the current comprehensive BE/E course tests. Data obtained from comparisons of test scores for groups using the revised material at different locations revealed statistically reliable (but small) improvement over the groups using the current course materials. However, on the diagnostic tests, most of the students in both groups continued to make substantial numbers of errors. Although analysis of the data from these groups is incomplete,

students' errors were the same type as before. Whether or not there are declines in the different error types that can be attributed to the revision of the materials is yet to be determined.

CONCLUSIONS AND RECOMMENDATIONS

Research designed to analyze error patterns in student responses to circuit problems reveals the extent of student misunderstanding and provides suggestions both for practical testing and changing training materials to enhance student learning and, hopefully, their future performance on the job. The difficulty students have in solving circuit problems seems due to imperfect conceptual or mental models of circuit functioning. These imperfections can be summarized by a few rules and then systematically diagnosed by appropriate tests. At the least, diagnostic testing of this kind should be incorporated into course procedures. The reasons that current tests do not indicate the serious deficiencies existing in student learning are not yet definite. However, it seems likely that students concentrate so much on solving the quantitative equations, emphasized by current teaching and testing, that they tend to ignore circuit functioning. This idea needs to be tested in future work.

APPLICATION

The BE/E school adopted some of the qualitative test items used in the diagnostic test. When students made many errors on these items, instructors examined and revised the corresponding instructional materials. Although our evaluation of these revisions is incomplete, they may have caused the slight improvement performance noted on the course tests. These course materials will be used in all BE/E schools starting in November 1985. The training command has requested that we evaluate the new materials and compare the effectiveness of the current self-paced delivery system with a lecture-based one, beginning in April 1986. The diagnostic tests developed here will be used in these assessments.

PLANS

Plans for the coming year include continuing the analysis of the existing data. Further studies of the effects of the structure of instructional materials on student understanding will be undertaken. We will continue to develop and test ways of identifying the problems students have in learning basic electricity and assist with the evaluation of new course materials. Methods are being developed to examine the students' conceptions of current, circuit, power, etc. Students' capability for working with equations and in qualitative reasoning, which are assumed in the course, will be examined. Course materials will be prepared specifically to overcome student misunderstanding identified by the diagnostic tests and their effectiveness in reducing or eliminating these learning flaws will be tested.

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COGNITIVE AND EMOTIONAL PROCESSING

Barbara A. McDonald

A need for the Navy to understand cognitive processing exists because of applications to training. Usually, the influence of emotion on cognition is not addressed even though many Navy tasks are performed under emotion-producing conditions. A model is presented which does include emotion and characteristics of the individual in cognitive processing. It promises a better understanding of individual cognition.

INTRODUCTION

Models of human cognition, which influence educational research, assume that information processing is continuous and rational whereas emotional processing is intermittent, and if anything, exerts an irrational effect on cognition. Both cognitive and emotional processes are continuous and simultaneous, and the assumption of rationality for either is misguided. Further, although cognitive and emotional processes may be separate processes, they are interactive. In fact, it will be shown that emotion is needed to interpret cognitive processes. As it happens, everyday experience and experimental evidence suggests that behavior patterns do not make much sense when explained by totally cognitive processes, anyway. A model that accounts for more person-oriented impacts on information processing is needed. The purpose of this paper is to discuss work on such a model at the Navy Personnel Research and Development Center.

In recent attempts to relate emotion to cognition (Bower, 1981; Izard, 1984; Lazarus, 1984; Mandler, 1984; Tompkins, 1981; Zajonc, 1980), several theorists have assumed that emotion affects cognitive processing only after first being appraised by cognitive processing. The issue is whether emotion needs to be recognized by the individual before it can influence cognitive processing. In fact, Lazarus says the question is, "How cognition shapes emotion." Another perspective on the interaction between cognition and emotion concerns the storage of emotion. Bower, for example, suggests that each specific emotion is stored in memory as a node with associative pointers to its many aspects; thus, emotion is stored in memory the same way any other concept is stored. The ways phenomena are investigated ranges from looking at preferences (Zajonc, 1980), to memories for events, to storage of emotionally laden memories. With the exception of Mandler's, no model deals with ongoing, simultanecus information and emotional processing. Furthermore, none has emphasized the characteristics of the individual and how they might mediate the relationship between cognitive and emotional processing.

The model developed in the present research differs from the others. It emphasizes simultaneous ongoing cognitive and emotional processing, as opposed to the storage of emotionally related information or labeling of emotion. The model also considers the person-related variables critical, i.e., the person

who is doing the processing is important. Finally, this model does not consider a direct effect of emotion on cognitive process, but rather looks at an indirect effect mediated by individual difference filters.

A MODEL OF COGNITIVE AND EMOTIONAL PROCESSING

This work is particularly directed toward explaining simultaneous cognitive and emotional processing in the ongoing "here and now." When information is processed in any situation, the cognitive processes such as attention, perception, and memory operate on the information so it can be understood and stored for later use. The model to be described here adds to the cognitive model by including characteristics of the individual, and the emotions of the individual, and shows how they play an important part in how the information will be processed. Figure 1 describes the relationship between characteristics of the individual, emotional arousal, and cognitive processing. This diagram shows that instead of affecting cognitive processing directly, emotional arousal affects cognitive processing indirectly by activating the appropriate individual difference "filters." The individual difference filters that operate may include, for example, personality variables, the self-concept, and perceptual, cultural, and prior experience factors. The present work focuses on personality, self-concept, and prior experience as filters.

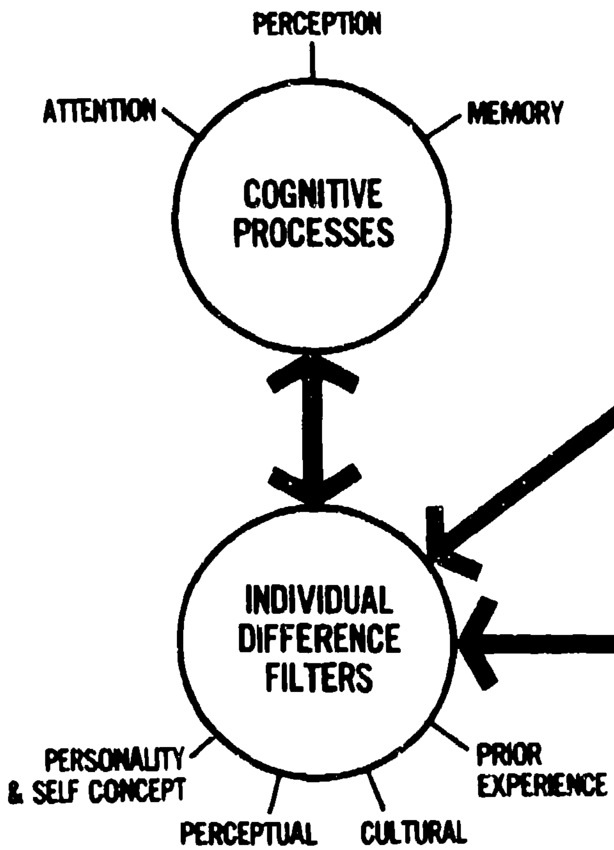

Figure 1. Processing of information depends on the combination of emotional arousal and individual difference filters.

ASSUMPTIONS AND COMPONENTS OF THE MODEL

Both emotional and cognitive processes are ongoing within an individual at all times. Whereas cognitive processes transform information, emotion transforms physical and chemical energy into autonomic arousal. In fact, separate neuroanatomical structures have been postulated for cognitive and emotional processing. The limbic system has been called the "emotional brain" and the hypothalamus has been implicated in cognitive processing (Zajonc, 1980; Izard, 1984).

The knowledge base (the specific information being processed) and how the individual difference filters work are also features of the model. First, the model assumes that when it comes to processing incoming information, the person usually processes information from past experiences as well as the new information that is coming in. The extent to which old information is processed, as opposed to the "pure" cognitive processing of new information, depends on the intensity of emotional arousal at the time and how much the new information triggers a response from the filters. The filters interact with emotion and cognitive processes by generalizing from new (incoming) stimuli to past (experienced) stimuli. They act to make the person see problem elements in the same way over time, to making decisions in a similar way over time, and to narrow perceptual attention, for example. The cognitive system may not "know" that emotion is operating in the sense of having labeled the emotion. People often distort or deny emotions and their effects. Mechanisms that account for this in personality theory are called defense mechanisms.

The individual difference filters interact with emotional arousal, cognitive processes, and the information being processed at the moment (knowledge base). Emotional arousal determines the salience of the different filters, while the filters influence the level of emotional intensity, especially in relationship to the knowledge base being processed. Some information will be more emotionally laden for one person than another, depending on past experience. The relationship between the filters and cognitive process is an important one because the filters have been shaped over time through interaction with cognitive processes.

In the model, the fact that filters are necessary to influence cognitive process is assumed partly because emotions do not affect individuals in the same way. This has often been dealt with by postulating "individual differences"--personal characteristics that are measurable. We are taking individual differences a step further in suggesting that they have functional properties that influence cognitive processing. Filters are particularly interesting because they influence cognitive processes to a greater or lesser extent based on the intensity of emotional arousal. The intensity of emotion aroused in combination with the filters determine the aspects of the knowledge base that will be salient.

EXAMPLES OF FILTERS

As an example, consider how personality and self-concept operate as a set of filters to cognitive processing. In general, personality characteristics and an individual's self-concept filter cognitive processing by predisposing a person to handle information in certain ways. Among the personality characteristics

relevant to the processing of information are predisposition to levels of anxiety, defense mechanisms, and coping strategies. A person characterized by high anxiety would be more likely to experience a narrowing of attention and subsequent "mental blocks" on test items. A person who handled anxiety by getting angry would perhaps blame the instructor for a poor grade instead of attempting to find out what the solution to the problem was. In terms of self-concept, people's feelings are usually tied to their self-concept so that if they feel they are competent, they will tend to explore more hypotheses, test more solutions, and stay at problem solving much longer than a person who feels self-doubt. Thus, self-concept "filters" both perception of the task ("I can do this if I keep trying") and the processes called up to perform the task.

Prior experience operates as a very effective filter because familiarity is a big factor in determining how information will be processed. Prior experience affects what will be attended to, what will be of interest, how comprehension will proceed, what will be remembered, and how information will be used in the future. Prior experience helps filter information according to stereotypes and prejudices, in the best and worst senses. Experience can blind a person to new aspects of the situation but it can also cut short the laborious procedures of decision making.

HOW THE MODEL WORKS

In most information processing experiences, people deal with information in ways that are comfortable for them. They use routines that fit what they expect to learn and how they have learned in the past. As shown in Figure 1, cognitive processing is affected by emotions as they influence an individual's filters. People, in general, process information with a bent toward what they are interested in, what they know best, what threatens them the least, what they are culturally familiar with, what they need to know, and many other things. In this way, emotions can influence cognition by filtering the use of cognitive processes such as the attentional, perceptual, and memory systems. Emotion does not affect cognitive processing directly but does affect the salience of the individual difference filters that do. This interaction between emotion and cognition happens moment-by-moment as people process information. It does not have such a big effect that it seriously distorts the cognitive processes in most situations; that is, the information being processed is usually more important than the filters. The role of filters under conditions of low arousal, then, is to automatize cognitive processes, making shortcuts of many decision points. A qualitative shift in the processing of information can take place, however, when strong emotions are aroused, so the mutual influence of cognition and emotion can have a big impact. It is at this point that highly filtered cognitive processing takes place.

When emotional arousal is high (either positive or negative), its influence on cognitive processing can be extreme. A reaction (most likely a physiological reaction) within the person changes the way in which information is processed. At this point, there is extreme selective enhancement of individual difference filters. Although activation will not necessarily occur on a conscious basis when emotions are aroused, an individual has less energy to moderate the use of all the filters that generally operate and the filters start determining the way the information will be dealt with. In this case, information will be distorted (even if it is to the positive) and the resulting reactions, decisions, opinions, and memories for the event will be more extreme and reflect more of the individual's biases.

One can, therefore, view the dynamic interplay between emotion and the filters as existing on a continuum. With low arousal, the filters are present and working, but they are fluid, the effect is there but the person is still mainly processing information. With medium level arousal, the person is attending to information but is actively searching for coping mechanisms to deal with the processing demands (either because there is emotion related to the specific information being processed or because there is competing, external emotion unrelated to the current processing task). At a high level of emotional arousal, the filters exert the most rigid influence over cognitive processing.

The primary features of this model are (1) the simultaneous, ongoing nature of both cognitive and emotional processing, and (2) the way in which the individual-difference filters operate between these two processes. An experimental assessment was therefore desired to allow observation of these features.

THE STUDY

The experimental method was developed to meet several criteria: (a) ongoing behavior needed to be observed within a scenario that allowed simultaneous collection of performance data and emotional reactions, (b) similar conditions had to be present for all subjects, (c) the task needed to be observed under normal as well as emotion-producing conditions, and (d) the task had to be realistic and absorbing for the participants.

The experimental scenario developed to meet these criteria was a computer-based game of military tactics. A pilot study tested the feasibility of the experimental scenario as well as investigated the appropriateness of the suggested model of simultaneous cognitive and emotional processing.

In the experiment, seven Navy electronic warfare specialists who were either tactics experts or novices played a computer-based game of military tactics. Three conditions were used: in the first session, the game was played under normal conditions; in the second session, the game was emotion-producing; in the third session, normal conditions were used again. The computer collected data on the accuracy of tactical decisions, the skill strategies used, and the timing of strategy use. All three sessions were tape-recorded to capture emotional reactions. The experimenter's role was to probe the player for strategy and content knowledge. This experimental situation was successful in allowing the subjects to play the game while being observed. Observed were score decrements, strategy differences, timing changes, and changes in decisions made. In addition, emotion was observed and recorded.

This familiar military scene cannot be understood without considering the effects of emotional arousal.

The game was very realistic and produced identifiable emotion. There were differences in behavior from session 1 to session 2 (when the conditions of the experiment changed) and emotions changed quite a bit under the second condition. The way emotion was expressed was also different, depending on the personality and self-concept of each individual.

One finding which was very surprising to the experimenter was that in the conversations that ensued in the third session, the return to normal gaming, all but one person discussed more personal information than in the first session. Conversation centered around job-related experiences which had either caused them great pain or had resulted in failed expectations. An interpretation for this finding is that the stressful game condition elicited reactions similar to situations experienced in the past. In general, the men seemed to feel comfortable expressing emotions to the female experimenter.

CONCLUSIONS

The results of this study are preliminary. Many issues still need to be addressed in the research and at least one other group must be assessed. Objective measures of emotional arousal will be collected in future research. However, the findings to date are very encouraging.

The simultaneous nature of both cognitive and emotional processes was observed and the effects of emotional arousal on cognitive process as moderated by the individual's characteristics was observed as well. Further work to assess this model of cognitive and emotional processing is planned.

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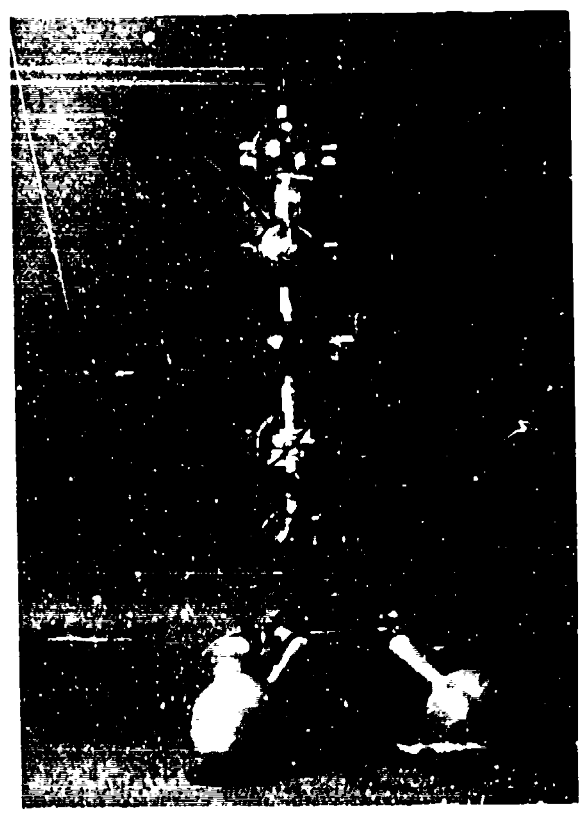
COGNITIVE FACTORS IN LEARNING AND RETENTION

Paula J. Konoske
John A. Ellis

Procedural tasks, which consist of an ordered sequence of steps performed on a single object or in a specific situation (e.g., preventive maintenance), comprise the majority of tasks performed in the military. The Navy instruction for these tasks is usually a sequence of steps with one goal that requires rote memorization. There is little explanation about the system and how the steps interrelate. Since procedural skills are often not retained well in memory, this research examined methods for designing instruction that make procedural skills more resistant to forgetting. Elaborated instructions that provided a how/why explanation prior to learning a procedural task were shown to facilitate retention of that skill. The results are relevant to the design of Navy instruction with respect to how much "theory" is presented and the effect of this on the length of the training pipeline.

PROBLEM

Recent surveys have found that procedural tasks comprise the majority of tasks performed in the military Fredericks, 1981; Tarr, 1985; Van Kekerix, 1983). Further, Campbell, O'Conner, and Peterson (1976) found that procedural tasks are the most important and necessary type of task for Navy mission readiness. Procedural tasks consist of an ordered sequence of steps or operations performed on a single object or in a specific situation. They involve few decision points and are generally performed the same way each time the task is done. Procedural tasks vary in (1) the amount of planning required to accomplish the task, (2) the number of steps and subprocedures required to accomplish the task, (3) the amount of cueing built into the task, (4) the number of decision points, (5) whether or not the order the steps are performed can vary, and (6) whether the goals of the task are internal or external to the task, system, or situation (e.g., operation vs. maintenance). Military personnel in technical ratings must



Model crane that was used by subjects for testing procedural task retention.

maintain high levels of procedural skill and knowledge to be able to perform their jobs successfully. Unfortunately, research has shown that procedural tasks are frequently not well retained (Ellis, 1979; Hurlock & Montague, 1982; Schendel, Shields, & Katz, 1978; Vineberg, 1975;). A possible solution to this retention problem and the focus of this research is to develop methods for designing instruction that make procedural skills more resistant to forgetting.

This paper describes briefly (1) the development of and research support for a taxonomy of qualitative explanations for teaching various types of procedural tasks, and (2) three experimental studies of the effects of presenting qualitative explanations on learning and retention of an assembly procedural task.

BACKGROUND

Most instruction for procedural tasks is "lean." That is, procedural tasks are most often taught as a linear sequence of steps with a single top-level goal. The instruction typically contains little explanation about the system or situation and how the steps interrelate, and requires rote memorization. This research investigated the effects of presenting qualitative explanations or elaborated instructions on learning, performance, and long-term retention of procedural tasks. Qualitative explanations are what Navy instructors and training developers are talking about when they use the word "theory." Because of the controversy in Instructional Systems Development (ISD) and Navy technical training over how much theory to give students, it is important to determine when and how much theory should be presented when learning specific types of procedural tasks. The reason for this is that adding theory or qualitative explanations to instruction lengthens training. However, adding theory may enhance learning and retention. The rationale for this notion is that qualitative explanations enable learners to build mental models or concrete cognitive representations of systems and tasks.

Research has shown that providing students with supplemental explanations sometimes facilitates learning and retention of procedural and complex rule- and principle-based tasks (Gentner, 1980, 1981; Kieras, 1981; Smith & Goodman, 1982; Sturges, Ellis, & Wulfeck, 1980; Tourangeau & Sternberg, 1982). However, in a review of the literature, it was discovered that very little work had been done on procedural tasks and that various authors discuss and define qualitative explanations, analogies, etc., and procedural tasks in different ways (Smith & Goodman, 1982; Stevens & Steinberg, 1981). Based on this literature review an operationally defined taxonomy of types of qualitative explanations was developed. The types are linear (what), structural (how/why), and functional (how/why). Linear explanations provide the student with inventory information about <u>what</u> to do with the system or in the situation, structural explanations provide information about <u>how</u> or <u>why</u> the system is constructed, and functional explanations provide information about <u>how</u> or <u>why</u> the system/situation works. These types incorporate the kinds of explanations described by others and they have the advantage of being relatively easy to define operationally.

After the types of explanations were identified and defined, the research relevant to each type was reviewed. Then the types of explanation necessary for learning specific procedural tasks were identified. Because procedural tasks differ in a variety of ways, the initial part of this

Table 1

Type of Procedural Task and Type of Theory That May Improve Retention

Type of Procedural Task	Type of Presentation: Linear	Structural Theory: How	Structural Theory: Why	Functional Theory: How	Functional Theory: Why
Operation	*	*	*	+	+
Maintenance					
Repair	*	+	+	+	+
Assembly	*	+	+	+	+
Paper-based					
Filing forms	*	+			
Formatting documents	*	+	+	+	
Locating information or objects	*	+	+	+	+

Note. Qualitative explanations (theory) can be direct or analogical.

*Indicates that a theory can be applied to the procedure.

+Indicates that teaching the theory behind the procedure may facilitate performance/retention.

process involved identifying the types of procedural tasks. Four different "classes" of tasks were identified: (1) operator, (2) maintenance/repair/assembly, (3) paper-based, and (4) locating information or locating objects. Table 1 shows the types of explanations that can be used with the various types of procedural tasks.

APPROACH

One possible solution to the problem of information retention that has not received much attention is the notion that qualitative explanations, elaborated instructions and analogies enable learners to build mental models or representations of systems and tasks, which in turn facilitate learning, performance, and retention. The approach of this research was to examine empirically the effects of various types of explanations on learning and retention of procedural tasks.

The task consisted of assembling a model crane. The subjects, enlisted military personnel (experiments I and III) and college undergraduates (experiment II), were randomly assigned to either a linear/structural instruction group, a functional instruction group, or picture only group, and were scored on speed and accuracy of constructing the model. Immediate and delayed (one month) performance testing was administered to all subjects.

RESULTS AND DISCUSSION

The results from experiments I and II indicated that the subjects who received functional qualitative instructions were better at recall and performance of the model assembly than the subjects who received linear/structural qualitative explanations. However, results from experiment III did not show such an advantage for the functional qualitative explanations over the linear/structural explanations. The findings in experiment III are probably the result of a ceiling effect. The military subjects in experiment III reported on an experience questionnaire that they had more mechanical experience than did the college subjects in experiment II (experiment I subjects did not receive an experience questionnaire). The less experienced college subjects (experiment III) and military subjects from a nontechnical ratings (experiment I) appeared to benefit more from the qualitative functional instructions than did the experienced military subjects (experiment II), perhaps because the military subjects in experiment III already had enough mechanical experience to make the functional explanations redundant.

CONCLUSIONS

In summary, providing additional explanations can be beneficial. However, the different results for different levels of experience point out the importance to training designers in considering prior experience and background variables when prescribing guidelines for instruction. Instructional designers are encouraged to consider the interactions between the learner's knowledge structures, the structure of the information content, and the structure of the task when developing instruction. Instructional developers should consider the "trade-offs" in training time and performance for the various types of explanations when designing instruction.

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REWARD SYSTEM DESIGN AND PERFORMANCE [1]

Delbert M. Nebeker

Productivity improvement has become vital to the Navy's success in meeting its defense commitments because of the expansion of fleet operations with tighter fiscal and manpower constraints. Navy managers have, therefore, made productivity improvement of organizations and employees a high priority. Some innovative reward systems to motivate and guide productivity have been successful. However, there is controversy over whether or not performance standards should be easy or difficult, and the size and types of rewards. For these questions, no acceptable evidence suggests which, if any, of the many alternatives is best and when it should be used. This research compared the effectiveness of several different reward systems. The combination of easy performance standards and larger rewards for exceeding these standards produced the largest performance improvements. A second experiment is underway and will be completed in early FY86. All of the systems produced cost savings as compared to straight wage payment, and several produced larger performance improvements than the others.

PROBLEM

Improving the productivity of Navy organizations and employees is a high priority for Navy managers. Increasingly severe fiscal and manpower constraints during the expansion of fleet operations make productivity improvement vital to the Navy's success in meeting its defense commitments.

BACKGROUND

Several programs have successfully increased productivity in Navy organizations by using innovative reward systems to motivate and guide productivity improvements (Nebeker & Neuberger, 1985; Shumate, Dockstader, & Nebeker, 1978). However, despite these successes, we know very little about designing optimal reward systems. The recommendations found in research and in practice on the proper design of these systems are contradictory. For example, serious conflict exists over whether easy or difficult performance standards should be used to determine who is rewarded. Likewise, disagreement and controversy abound over the size and type of the rewards. Other questions are raised about how to tie the amount of the reward to the amount of the improvement in performance. For these and other questions about the parameters of reward systems, there is no acceptable evidence suggesting which, if any, of the many alternatives is best and when it should be used.

This research compares the effectiveness of several performance standards and rewards on employee productivity.

[1] Cost shared with Center 6.2 funding ($50K from PE 62763N).

APPROACH

This research was conducted in the Organizational Systems Simulation Laboratory (OSSLAB) at the Navy Personnel Research and Development Center. The OSSLAB simulates working conditions and hires actual employees, who work under a variety of management practices and/or styles. The experimental and laboratory conditions used make it possible to collect extensive and accurate performance and behavioral data on the workers. Actual observed differences in productivity, as well as activity, satisfaction and stress, provide the bases for developing theory and recommending field applications.

This experiment investigated the joint effects of the difficulty of performance standards and the magnitude of rewards. Twenty-four proficient keyboard operators were recruited and hired (at $4.89 per hour) to enter and maintain references in a data base for searching and retrieving the scientific literature. The employees were divided into two equal shifts that worked two 4-hour shifts a week for eight weeks. A work-sample test given to measure ability revealed substantial variability within shifts, but no significant differences between the two shifts.

Both shifts performed in a baseline or control condition before the introduction of performance standards and financial incentives. Once performance had stabilized in the baseline condition, performance standards were set for both shifts. One shift was assigned a difficult performance standard, which was set at the 90th percentile of the shift's baseline performance (6600 keystrokes per hour). The second shift was assigned an easy standard, which was set at the 20th percentile of their baseline performance (4800 keystrokes per hour). When employees exceeded these performance standards, they qualified for a reward. The magnitude of the reward depended upon the experimental condition. Both shifts were offered small incentives during weeks 3 through 5 and large incentives during the last three weeks. The small incentive was a 15-percent "sharing rate"; that is, 15 percent of the labor cost savings from performance above standard were "shared" with the responsible employee. For example, an employee performing 10 percent above the standard received a 1.5 percent increase in hourly pay. The large incentive was a 50-percent sharing rate; an employee performing 10 percent above the standard earned a 5 percent increase in pay.

RESULTS AND CONCLUSIONS

The results proved to be very interesting in view of the fact that many researchers have argued for difficult performance standards (e.g., Locke, Shaw, Saari, & Latham, 1981). We found that the combination of easy performance standards (80% of employees were already exceeding the standard) and larger incentives for exceeding these standards (50% sharing rate) produced the largest performance improvements (see Figure 1). Performance under difficult standards improved over the baseline but was not affected by the magnitude of the incentive offered. It is interesting to note that all the combinations of reward amounts and performance standards produced substantial cost savings (from 14% to 24%) over straight wages paid in the baseline condition.

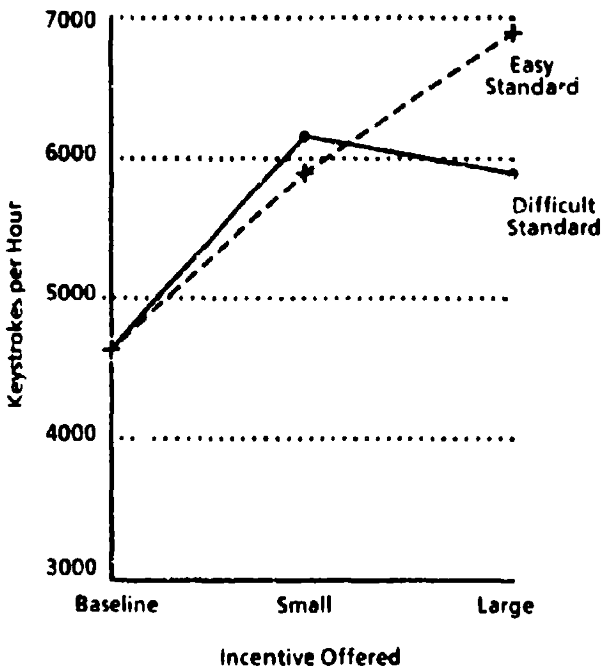

Figure 1. Employee performance as a function of incentives offered and difficulty of performance standard.

From these data, as well as other evidence, we conclude that:

1. Setting difficult performance standards is not justified by performance improvement or cost considerations. Assuming employee acceptance of the performance measurement system is desired, the use of difficult standards is even less justified.

2. Under linear sharing rate systems, such as the one used here, the optimum magnitude of the rewards is approximately 50 percent of the wages saved by exceeding productivity standards.

3. Any of the designs used here promise large cost savings when properly implemented. Perhaps it is this generalized success across a variety of designs that has produced contradictory recommendations in the literature to date. Without a direct comparison between competing alternatives, such as was done here, it is difficult, if not impossible, to determine which particular design is most effective.

PLANS

A second experiment in the OSSLAB begun in FY85 will be completed in early FY86 under exploratory development funding. This experiment compares the effectiveness of increasing the magnitude of reward in accelerating amounts instead of constant amounts for incremental increases in performance. Evidence supporting the superiority of the accelerating magnitudes of rewards would have a significant impact upon both practical and theoretical thinking.

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RELATIONSHIPS BETWEEN MANAGEMENT PRACTICES AND ORGANIZATIONAL PERFORMANCE

Mark C. Butler
Kent S. Crawford

The internal management practices of two Navy logistics organizations similar in size, structure, personnel composition, and function, but differing in effectiveness were examined. Managers in the more effective organization maintained efficiency and adapted to change by using creative and flexible management practices to meet their facility's goals.

PROBLEM

Navy logistics organizations are faced with the challenge of meeting increasing demands with decreasing resources. At the same time, major developments in technology, management innovations in business and industry, and increasing administrative constraints including increased accountability are also changing the logistics environment of the 1980s.

Implementation of organizational improvements and innovative management practices could improve operation of Navy logistics organizations. However, we do not clearly understand those organizational and managerial factors that contribute to effectiveness under conditions of accelerated change. The practices with the greatest potential for improving mission accomplishment need to be identified and evaluated.

BACKGROUND

Increasingly, organizational researchers and practicing managers are concerned with issues related to productivity and performance. Specifically, they want to know why some organizations, or organizational subunits, perform more effectively than others even though all have similar structure, size, personnel composition, and function. To address this question, some researchers are examining the impact of external factors--those outside the immediate organizational context--on the effectiveness of an organization. For example, consumer assessment of organization performance is currently viewed as an important and frequently overlooked externally derived effectiveness factor (Jobson & Schneck, 1982; Zammuto, 1984). Other researchers argue persuasively that the traditional emphasis on studying the impact of internal factors, such as organizational goals and problem solving style, should be retained and expanded to include assessing organization culture (Kiefer & Stroh, 1983).

Although the Navy's logistic organizations operate within a rapidly changing environment, their structure, technology, personnel composition, and reporting requirements (i.e., chain of command) are similar. To understand differences in performance and effectiveness, we need to determine areas in which homogeneous logistics organizations have actual control or discretion. In this instance, internal

Effective management of people makes a significant contribution to productivity in Navy industrial organizations.

issues related to organizational effectiveness rather than external management factors should be examined because external factors are heavily constrained by higher level policies.

Determining the relationship of a number of management practices to organizational performance would facilitate development of a model of organizational functioning to identify the management practices that enhance individual, subunit, and organizational performance. Such a model would recognize that some management practices are specific to certain settings, while others are more generic and applicable across settings. In short, some management practices probably (1) vary across organizational settings, (2) are unique to certain settings, and (3) are associated more with high versus low performance effectiveness.

GOAL

The specific goal of the present study was to identify the internal management practices that differentiate between effective and ineffective logistics organizations.

APPROACH

To identify key management practices, researchers selected two large naval industrial organizations for study--one traditionally performing at a high level of effectiveness; and the other, at a low level. Selection was based on the same institutional criteria that the naval headquarters command uses to evaluate the organizations' ability to meet their stated goals.

Interviews with key managers at both organizations identified the significant management practices currently in use. The interview data were also the basis for development of an extensive management practices questionnaire (MPQ), which was administered to comparable groups of managers in each setting.

RESULTS

Two major areas distinguish the participating organizations from each other--goals and management practices. In the area of goals, top management in both facilities reported that the success of their respective organizations depended on maintaining efficiency and adapting to change. While both participating facilities emphasized achieving these goals by adhering carefully to "bottom-line" outcomes such as schedule, cost and quality in the more effective facility, there was an increased emphasis on improving internal efficiency (e.g., exceeding standards, reporting accurate information), eliminating productivity impediments, and enabling personnel development. In the area of management practices, managers in the more effective organization reported engaging in proactive, ongoing development activities, having a clear understanding of the structure and purpose of their organization, stressing a relatively high degree of coordination of work flow, and possessing adequate authority and information to perform their respective managerial functions.

CONCLUSIONS

Managers in the more effective organizations differed from managers in the less effective organizations in the goals they emphasized as well as the management practices they employed to achieve those goals. The effective organizations seem to encourage and support greater creativity and flexibility in managerial decision making. Future efforts will attempt to replicate these findings in less homogeneous organizations, as well as examine how individual difference measures moderate these findings.

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ANALYSIS OF COGNITION IN NATURAL SETTINGS

Edwin Hutchins

Most thinking jobs in the Navy are conducted by groups of people working together, but the study of cognition has traditionally used the individual in isolation as the unit of analysis. Very little is known of the properties of systems of socially distributed cognition and appropriate theory and methods for studying such systems are currently lacking. This research took as its basic unit for analysis the piloting team of a large Navy ship. This approach enabled much of the internal behavior of the system to be observed in a way that is not possible with processes internal to individuals. The results revealed some fundamental differences between individual and socially distributed cognition. An understanding of the nature of cognition in real world settings is important for diagnosing performance inadequacies, training, designing job performance aids, and human factors design of operational environments.

BACKGROUND

Most thinking jobs in the Navy as well as in nonmilitary settings are accomplished by groups of people working together. The research literature in cognitive anthropology and cognitive psychology that concerns naturally situated cognition assumes as a primary unit of analysis, the individual in isolation from other individuals as well as from a world of action and mediating technologies. In the most interesting and characteristically human activities, however, the cognitive system clearly includes two or more minds, a shared culturally meaningful task, a social organization, and technologies such as literacy that mediate and externalize the performance of individual cognition. The cognitive properties of such systems of socially distributed cognition are certain to differ in important ways from the properties of the cognition of individuals. Yet, we know very little about how such systems actually work.

PROBLEM

An understanding of the nature of cognition in real world settings is important for (1) diagnosing performance inadequacies, (2) providing training that is relevant to the actual job to be performed (3) designing performance aids, and (4) designing operational work environments. Furthermore, as work environments become more automated and include more intelligent systems that interact in fundamentally cognitive ways, we must develop an understanding of how systems of distributed cognition work. At present, however, a lack of appropriate theory and method hampers our understanding of cognition in settings outside the laboratory.

APPROACH

The first step in the project was to select a task domain in which a system of socially distributed cognition is in

operation. The piloting team on the bridge of a large Navy ship was selected because the following important properties make it amenable to study:

1. A group of six individuals jointly performs a few culturally well-defined behaviors. Therefore, we know that the task is socially distributed and what is supposed to be done is known precisely.

2. Several mediating technologies and representations are utilized. These include literacy, the use of charts, graphs, and other external computational media as well as electronic devices that perform parts of the computation.

3. The principal investigator has more than 25 years of experience with the navigation procedures involved. This means that the researcher could easily achieve a degree of credibility in the eyes of the team under investigation and that, during the analysis process, the researcher could concentrate on discovering the properties of the socially distributed cognitive system rather than on trying to figure out what the team was trying to do.

The most fundamental theoretical innovation of the approach taken here is in the boundaries of the cognitive system that is to be the unit of analysis. Rather than looking primarily at a single individual and then trying to see how a team of individuals could function jointly, this project took as the fundamental unit a group of people jointly performing a single task. Communication among the group members is seen as an internal process of the cognitive system; computational media (e.g., charts), as internal representations of the system; and the computations carried out, more as internal processes of the system. Yet, because the cognitive activity is distributed across a social network, these internal processes and internal communications are directly observable. If a cognitive psychologist could get inside a human mind, he or she would want to look at the nature of the representation of knowledge, the nature and kind of communication among processes, and the organization of the information processing apparatus. In such a fantasy, the underlying processes would be obscured at some level of detail. If these observations could be made, however, any cognitive psychologist would be very happy. With systems of socially

Most thinking jobs in the Navy are conducted by groups of people working together.

distributed cognition we CAN step inside the cognitive system. The analysis in this project begins by attending precisely to things that the cognitive psychologist would attend to if he or she were given the opportunity to step inside a mind.

The data consist of written and audio-and videotaped observations of the behavior of the piloting team on the bridge of a Navy ship in high workload situations. The system's response to a true crisis situation was also observed and recorded. Data were collected during two at-sea periods in February and April 1985. Transcription and analysis of the data are now in progress.

DISCUSSION AND RESULTS

Initial analyses of the data show that detailed accounts of the internal states of the cognitive system can be constructed. Some aspects of the behavior of the distributed system mirror what we already know about individual cognition. The approach used here makes a good deal of the internal behavior of the system observable in a way that individual psychological processes are not. Much of what we see resembles what has been inferred about individual cognitive processes. Therefore, this research promises to provide a wealth of interesting hypotheses about the nature of individual cognition.

Still, the properties of socially distributed cognition differ from the properties of individual cognition in important ways. For example, suppose a procedure requires actions at several different locations. While an individual task performer must distribute those activities across time, a socially distributed cognition system may distribute activities simultaneously across space. Socially distributed systems also permit the simultaneous maintenance of different interpretations of, or competing hypotheses about, the current situation. The nature of the discovery and resolution of such conflicts through social interaction contrasts with the search for confirming information generally observed in individual cognition.

Finally, when a procedure is distributed across a group of individuals, procedural dependencies become social dependencies. While communication within a single mind seems to be relatively rapid, communication between individuals always depends upon the information-carrying properties of some external medium (i.e., spoken language or a diagram). This has implications for how to distribute tasks usefully across individuals. Consider the task of figuring out which features of the world correspond to which features on a chart. This task is not always easy for one person to do even when that person can consult both the chart and a representation of the world. However, the task becomes almost impossible when it is distributed across two individuals so that one has access to the chart, the other has access to the world, and they have access to each other only via spoken language (this situation sometimes arises aboard ship). This difficulty is caused by the bandwidth of communication required between the representation of the chart and the representation of the world being greater than that provided by the medium of communication between the two task performers.

PLANS

The transcription and analysis of the data will continue in FY86. As some aspects of the behavior of these systems seem amenable to simulation modeling, an attempt will be made to construct such models. The theory, method, and example analyses will be written up as a series of technical reports and as a monograph for publication. No further field research is planned at this time.

EXPERT SYSTEMS FOR FAULT DIAGNOSIS: STOCHASTIC PROCESSES

Donald B. Malkoff

Lack of precise information needed for reliable fault diagnosis and lack of time in which to make the diagnosis and act on it make coping with malfunctions during the operation of complicated control systems difficult for Navy personnel. The automated support operators need for fault diagnosis and decision making generally involves the use of computer "expert systems."

A method is proposed for the development of computer programs that automatically refine, correct, and complete the information used for decision making and automatically associate the pattern of system behavior following a malfunction with its eventual diagnosis. New computer hardware is on order to simulate malfunctioning of a real-time control system using the DD 963 ship propulsion lubrication oil system as a test bed.

BACKGROUND

Navy personnel encounter great difficulties in coping with malfunctions during the operation of complicated real-time control systems. In such systems, the time required for a response may be critical; the behavior of the system is influenced by random factors in the environment; and information overload exists. As a result, the total knowledge necessary for either a human operator or a computer expert system to make reliable diagnoses is often not available.

Attempts to provide the operator with automated support have generally dealt with well-defined routine procedures for system start-up and shutdown. The most pressing need, however, is for automated support for the tasks of real-time fault diagnosis and decision making. Automated diagnosis and decision making ordinarily involve the use of computer "expert systems."

The application of expert systems to the handling of malfunctions in real-time control systems has been problematic. The information needed for diagnosis by the computer program is often either missing, imprecise, or incorrect. Additionally, the environmental state of the process to be controlled may be changing unpredictably from time to time, causing significant variability in its behavior in response to malfunctions.

A possible solution to the problem of insufficient information for the diagnosis of malfunctions lies in the development of computer programs that are able to (1) automatically refine, correct, and complete the information data base used for decision making, and (2) automatically associate the pattern of system behavior following a malfunction with its eventual diagnosis. Computer programs having this capability are said to be able to perform "pattern recognition." In the case of gas turbine engine control, the elements that make up the patterns would include

sequences of the specific values of system variables such as temperature, flow rates, rotational speed, etc., of various engine components. Programs using pattern recognition can theoretically learn by association which patterns are indicative of specific malfunctions and continuously update these associations so as to adapt to changing conditions.

PROBLEM

Pattern recognition is not presently possible in systems where the timing of events following a malfunction is affected in unpredictable fashions by a multitude of unknown factors. For example, on one occasion that an oil reservoir begins to leak rapidly, the first sign of trouble may be the triggering of a low oil fluid-level alarm. On the next instance of this malfunction, the leak may be slower, in which case the first sign of trouble may be a low oil pressure alarm, or perhaps a high temperature alarm in the component being supplied by that oil reservoir. If, on every occasion of the same type of malfunction, its pattern of symptomatology differs, how can a computer expert system possibly learn to diagnose the cause? This dilemma is referred to as the "stochastic problem."

It will not suffice for the computer program to deal with the stochastic problem by attempting to remember all of the previous patterns that followed all previous malfunctions. Since there is an infinite variety of patterns that can occur, the computer's memory will soon be filled and unable to function. Furthermore, each new occurrence of a malfunction, because of the random factors, will be somewhat different than any of the previous patterns stored in memory. An exact match will never be possible. The computer expert system may not be able to recognize it as a familiar pattern.

APPROACH

In the method we propose for dealing with the stochastic problem, the pattern of system variable values following a malfunction is viewed as a sequence of significant events, for example, of the triggered alarms. The sequence is characterized in three ways: (1) the specific alarms that are triggered by a malfunction, (2) the order in which those alarms are triggered, and (3) the amount of time elapsed between successive alarms.

When a new occurrence of an as-yet undiagnosed malfunction produces a developing sequence of alarms, the sequence is NOT directly compared with previous sequences in memory. Instead, a list is constructed of all malfunctions that have been known in the past to cause this particular order of these particular alarms. At this stage, no attention is paid to elapsed times between alarms.

For each of the malfunctions on the list, a binomial probability curve is constructed based on that malfunction's recent history of time intervals for each alarm in the sequence. In other words, all previous manifestations of the same kind of malfunction are averaged and incorporated into a single curve for every event or alarm in the sequence. Now the newly occurring, undiagnosed sequence can easily be compared with each of the curves to determine the best match. In this manner, even before the sequence is complete, the most probable diagnosis can be made at every step of the way with increasing accuracy as time elapses following the onset of the malfunction.

While the description of this method may sound complex and be difficult to envision, it is remarkably similar to the methodology of medical diagnosis. The physician, in attempting to make a clinical diagnosis based on the patient's symptoms and on the clinical syndrome (the order, timing, and severity of the symptoms), compares the symptomatology of the present case with his model or conception of the TYPICAL, or USUAL symptomatology of various diseases. He recognizes that the specific symptomatology of a patient will seldom exactly match with any previous case. His models are nothing more than mental (or textbook) reconstructions of averages for the most probable sequences of symptoms, much in the manner of the sequence of probability curves for gas turbine engine alarms in our approach.

RESULTS

Preliminary paper-and-pencil analysis indicates this approach to be an effective one.

PLANS

New computer hardware has been requisitioned that will allow the simulation of a malfunctioning real-time control system. In particular, it will allow the incorporation of random variability into the timing of the system processes. The target system will be the lubrication oil supply to the reduction gears of the gas turbine engine unit of the DD 963 class of ships. A real-time computer expert system will be developed and tested.

BENEFITS

Should the approach be successful, it will provide a possible solution to the stochastic problem encountered in attempts to develop real-time expert systems, and provide a mechanism for constructing expert systems that can learn from experience and adapt to changing conditions. Both of these imply considerable potential benefits for military and civilian control systems.

MULTIPLE CRITERION OPTIMIZATION TECHNIQUES

Timothy Liang

Assigning over 500,000 active duty Navy enlisted personnel in some 300 distinct occupational specialties at 9 skill levels to jobs at naval activities and units all over the world is based on numerous complicated factors. These assignment problems hold unique challenges for the integration of multiple criteria decision making and large-scale optimization techniques.

In FY83/84, the Navy Personnel Research and Development Center developed a computationally efficient pure network flow algorithm modified to handle multiple objectives, which the Enlisted Personnel Management Center, New Orleans adopted as its main allocation/assignment planning tool for general detail personnel. However, other methodologies are needed to solve the large-scale multiple criterion Navy assignment problem with additional, more complex constraints such as required training or multiple skills. Large-scale integer programming and embedded networks were found to be insufficient for the problem. Work planned for FY86 will use aggregation-disaggregation theory to develop advanced techniques in more global resource allocation and management.

PROBLEM

Navy personnel assignment is a large complex and expensive operation. The annual permanent change-of-station (PCS) budget for assigning over 500,000 active duty enlisted personnel to 5,000 different naval activities and units as distant as Antarctica and the Indian Ocean is over $525 million. Personnel are assigned to either sea or shore duty jobs in about 300 distinct occupational specialties and at 9 skill levels. "Wholesale" allocation of personnel to fill quotas to major groupings of Navy units distinguished by geographical regions, types of duty, etc. precedes the assignment or "detail" of individuals to jobs within those unit groups.

Detailers match people to jobs using complex person/job eligibility criteria and numerous rules, regulations, and policies (multiple criteria). Detailers must be concerned with the global needs of the Navy (e.g., achieving an aggregate balance of scarce, highly skilled personnel among ships in the Atlantic and Pacific Fleets), the requirements and priorities of specific jobs, and the needs of the individuals (e.g., preferred location, skill utilization). Finally, detailers must make accurate and effective decisions within tight moving-cost constraints.

Decisions are made at the operational level where aggregate resource allocation plans must be linked with individual assignments as well as operational policies and constraints. Navy assignment "planners" and "operators" must be able to make explicit quantitative policy tradeoffs to negotiate and agree on the relative importance of the policy criteria and the flexibility in the execution of policy goals. Navy assignment problems hold unique challenges for the integration of multiple criteria decision making and large-scale optimization techniques.

BACKGROUND

The Navy Personnel Research and Development Center (NAVPERSRANDCEN) developed the theoretical and empirical approach for an integrated allocation and assignment system in FY83 and FY84. This system uses a computationally efficient, pure network flow algorithm modified to handle multiple objectives. The initial application allocated and assigned general detail personnel (i.e., those who have not yet obtained a specific occupational rating). Close contact with the Enlisted Personnel Management Center (EPMAC), New Orleans led to numerous improvements in the model. After testing, EPMAC adopted the model as their main allocation/assignment planning tool.

The pure network approach is adequate for occupations that do not require advanced training or multiple skills. Other approaches must be investigated and developed for complicated assignment problems such as those that involve classroom availability at training facilities. This work will continue under 6.3 funding.

OBJECTIVE

The FY85 objective was to investigate and develop methodologies to solve the large-scale, multiple criterion optimization Navy-assignment problems when additional, more complex constraints are added.

APPROACH

In FY85, solutions to solve the large-scale, multiple criterion optimization Navy assignment problem were sought by investigating the works of Professor Glen Graves at the University of California, Los Angeles, the leading expert in large-scale integer programming, and also the works of Professors Jeffrey Kennington at Southern Methodist University and Richard McBride at the University of Southern California, two leading experts in the field of embedded networks.

RESULTS

The large-scale integer programming approach is simpler and more straightforward than the network approach for mathematical formulation of the Navy assignment problem. However, the Navy assignment problem is much bigger than the current capacity of large-scale, integer programming codes.

The embedded network approach currently has the capacity to handle the size of the Navy assignment problem as well as the additional complex constraints that a pure network code cannot handle. However, this approach does not yield integer solutions, which are essential to the assignment problem.

PLANS

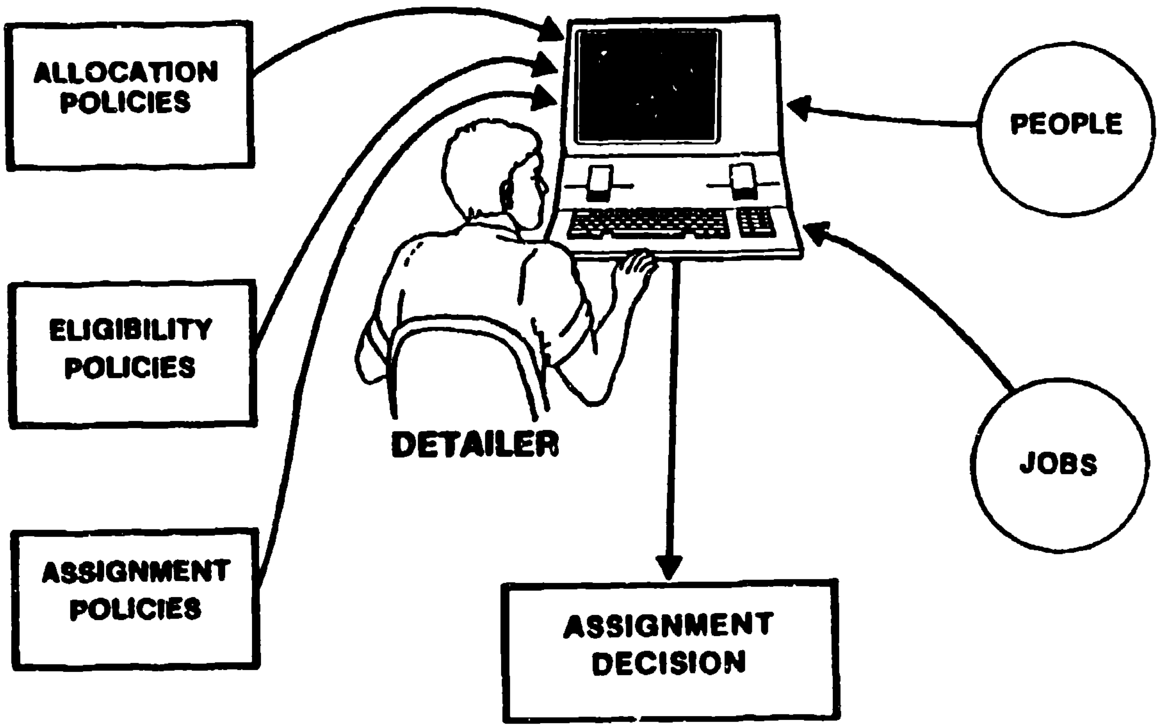
In FY86, additional research is planned to develop a network approach to handle large-scale problems with complex constraints and also produce integer solutions. Since adding complex constraints to a network reduces its computational efficiency, investigation of alternative methods will also be continued.

Two other related areas of research that will also be pursued are the use of (1) concepts of aggregation-disaggregation theory with cybernetics for more global resource allocation planning and (2) modeling techniques to allow more flexibility in controlling policy tradeoffs.

APPLICATIONS

Past research (FY83/84) was applied to an advanced development project (Personnel Assignment System) to develop an integrated allocation and assignment system for general detail and nominally trained enlisted personnel. Current research on the 6.3 project is aimed at developing similar systems for skilled enlisted personnel who require extensive technical training.

This technology will also be used with concepts in aggregation-disaggregation theory to develop advanced techniques in global resource allocation and management. Developing techniques for more effective execution of the PCS budget is just one example of an important application.



Navy detailers must consider multiple criteria in matching people to jobs.

INTERFACES FOR COMBAT DECISION SUPPORT

Frank Greitzer
Jerry Kaiwi
Ramon Hershman

Increased complexity in Navy combat systems has led to critical problems of system operability, increased demands on Navy users, and excessive training requirements. Integrating the human decision maker with intelligent support systems could reduce information overload and improve the effectiveness of combat systems operations. This research examined the design of intelligent interfaces for systems in which the human and computer are viewed as partners working together. Relevant human factors issues were identified and explored in a simulated command and control problem and a prototype intelligent interface, the intelligent tactical assistant, was developed. The work will progress to advanced development.

PROBLEM AND BACKGROUND

A critical problem facing the Navy is how to operate its combat systems more efficiently to realize their full technical capabilities and operational effectiveness. The major cause of inefficient operation is the extreme complexity of advanced weapon and sensor systems made necessary by the increased threat. We attribute the fact that advances in computer technology have not produced more operable systems to an emphasis on form and literal content of isolated user-computer transactions rather than on their purpose in the larger system. As combat systems become more complex, this approach leads to excessive training requirements and increased demands on Navy users.

Emerging interest in intelligent interfaces suggests that the interaction of two cognitive systems, the user and computer software, must be considered. This places a new emphasis on knowing the user's goals and intentions, the development of new tools and procedures, and the incorporation of contextual information. However, much of the thinking has focused on relatively passive environments such as word processing or data base searches. While some interface features that maximize "user-friendliness" transfer readily to combat systems, others may not be appropriate in high stress environments. Indeed, altogether new requirements may become evident in the combat domain. Thus, there is a need to define, investigate, and demonstrate concepts of intelligent interfaces toward their adoption in combat system design.

OBJECTIVE

The long-term operational objective of this effort is to enhance combat system performance by developing knowledge-based aids for information integration and manipulation. The technical objective is to develop a laboratory test bed to investigate enhanced interface concepts for improved user-computer collaboration.

APPROACH

The approach is to identify and investigate basic human factors issues related to integrating human decision makers with intelligent support systems. The context for this research was a simulated command and control problem implemented in a laboratory test bed. Issues were identified, and related man-machine interface concepts were explored in the laboratory and applied incrementally to the development of a prototype intelligent interface. This exploratory development draws from the fields of cognitive psychology, decision science, human factors, and artificial intelligence.

RESULTS

Determinants of Interface Design

The following four critical issues influence the design of the user-computer interface. The first two are well recognized, but the last two are often not addressed.

1. Task demands. The nature of the task, especially the goals, priorities, constraints, and procedures associated with it lead to critical design decisions for allocating functions among personnel, hardware, and software. From this basic

Intelligent interfaces may enhance the operability of systems in high stress Navy environments.

starting point, the design of the interface often falters when decision support functions are designed as sets of largely disconnected algorithms. The user is often overwhelmed when forced to cope with their proper utilization and management.

2. Hardware and software options. The availability of hardware and software limits the ultimate form and capability of the interface design. More importantly, the selection of hardware and software concepts determines the type and extent of intelligent interactions that the interface can accommodate.

3. Model of the user. The system designer's "model" of the user--be it implicit or explicit--reflects the user's abilities, limitations, biases, preferences, and experience. Inappropriate or inaccurate models lead to poorly designed systems that overestimate, underestimate, or ignore human performance factors that system support functions could accommodate.

4. Model of the system. The model of the system that the user acquires by training and hands-on experience is best thought of as the metaphor about the system's functional behavior that is conveyed to the user. In the worst case, the user perceives the system as a "black box." When its behavior is unsatisfactory or unexpected, the user's first response may be to ignore it or to turn it off. In general, a well chosen and well executed design metaphor will reduce training requirements, increase user satisfaction, and enhance system operability.

Command and Control Environment

Consider how the user-computer interface issues apply to the command and control environment. What are their implications for the design of interfaces for combat decision support?

Task Demands. Because the command and control environment is complex, dynamic, adversarial, uncertain, and time critical, it poses special difficulties and challenges for interface design. Complex information processing and the dynamic environment make extreme cognitive demands on command and the combat team. An intelligent adversary adds yet other dimensions of deception and countermeasures as enemy intentions must be recognized in the midst of uncertain, unreliable, and often contradictory data. Further, combat is a "high stakes" encounter in which operator errors may well be catastrophic and time is critical. In contrast to more passive applications, preventing errors is greatly preferred to correcting them and computer response times are not merely matters of user convenience. Time constraints (in the form of windows of opportunity) and limits in technology thus critically determine the division of labor between human and computer.

Hardware/Software Options. The decreasing cost of computer memory and processing increases the available options for combat system hardware and software. The so-called "expert systems" technology shows much promise. An expert system is a computer program that has the knowledge, procedures, algorithms, and heuristics necessary to perform a task typically done by humans. The most successful expert systems work in well-defined, manageable domains.

Typically, expert systems act independently (e.g., automatic detectors, trackers, and classification systems) with the user primarily monitoring and evaluating the output. Human factors research for such expert systems deals with traditional interface issues such as input/output modes, the use of color, menu design, legibility and display formats, and the use of new tools such as display windows and graphic pointing devices (the "mouse").

Further development of these "independent" expert systems will probably benefit Navy command and control systems marginally. What is needed is better integration of the user and the computer so that both partners truly collaborate in the decision making process. Although traditional human factors concerns are important in expert systems, the most fundamental human factors issue is to design the interface so that it promotes human-computer problem solving. Unfortunately, military systems seldom use collaborative designs. However, there is a great need for them in present and future combat systems.

Model of User. The operator/decision maker in combat systems is indeed resourceful, skillful, and knowledgeable. However, the typical design seems to assume that the user is always in control (i.e., aware of all action choices and system assets). In fact, memory and attention limits, the ability to integrate information, multiple task demands, cognitive biases, stress, and incomplete knowledge of the system's support capabilities constrain the user. An appropriate model of the user would incorporate these realities and lead to the design of more intelligent support systems.

Model of the System. The design metaphor of the computer as a staff assistant captures the kind of active collaborative support that intelligent combat decision aids require. Such an assistant must have extensive knowledge of the environment, as well as the procedures, strategies, and functions that complement the user's cognitive capabilities. A balance of initiative, cooperation, and faithful execution is essential.

Some plausible roles for an intelligent command and control assistant are to:

1. Provide easy access to tools.
2. Automate routine functions.
3. Execute specific subtasks on demand.
4. Inform the user of the status of tasks.
5. Remind the user to perform certain tasks.
6. Advise the user in selecting alternative actions.
7. Monitor progress toward the goal.
8. Anticipate requests to display or process data.
9. Test hypotheses.
10. Explain its behavior.

Additional, and perhaps more intelligent assistance must be defined in the context of specific applications, but, clearly, a passive interface will not suffice for this type of collaboration. Instead, advanced user-computer communication concepts are required to promote the full integration of the computerized staff assistant for combat systems design.

Research and Development Test Bed

Specifying intelligent interfaces for collaborative expert systems is far from complete and is an active research topic in the human factors, cognitive science, and artificial intelligence disciplines. Our research explores advanced concepts of user-computer collaboration in a laboratory test bed, called intelligent tactical assistant (ITA). ITA is a prototype aid for identifying ship contacts based on electronic and acoustic emissions and intelligence reports. Its data base contains sensor and weapons information and other descriptive data for 28 classes of Soviet ships. ITA provides tools for searching the data base quickly and integrating new reports with current information. It was initially implemented in the LISP language on a VAX computer. In FY85, ITA was redesigned (using C and LISP code) for the NPRDC System Simulation Facility's MASSCOMP computer. This version has a color graphics display to facilitate data integration and a mouse/window interface for ready access and manipulating of the data base.

PLANS

We plan to incorporate contextual knowledge in the form of system goals and the history of the interaction into ITA. ITA needs this contextual knowledge about means and ends in the contact identification problem to act as a true assistant. However, each partner in collaborative expert systems must have a model of the other's objectives and methods, as well as effective means of communicating status, questions, answers, etc. Thus, there are formidable human factors research issues in collaborative expert systems for combat.

The planned research will focus on the dynamics of an interface that can support both independent and collaborative efforts of the user and the computer. This focus suggests that multiple working surfaces will be required: A display of the current solution that reflects the team's progress, a display for the user to explore possible alternatives, and a display for the assistant to inform the user about ongoing analyses. Various questions then arise in the collaborative environment: Under what conditions should the assistant interrupt the user? What are the best forms for user-assistant dialogues? How much adaptation and flexibility does the combat system interface require? How does one evaluate the performance of the new partnership?

EXPECTED PAYOFF

The findings from this effort relate directly to fleet requirements for increased operability of combat systems. The results are expected to proceed to advanced development within three years.

DESIGNER: AN EXPERT GRAPHICAL DESIGN CONSULTANT

Louis Weitzman

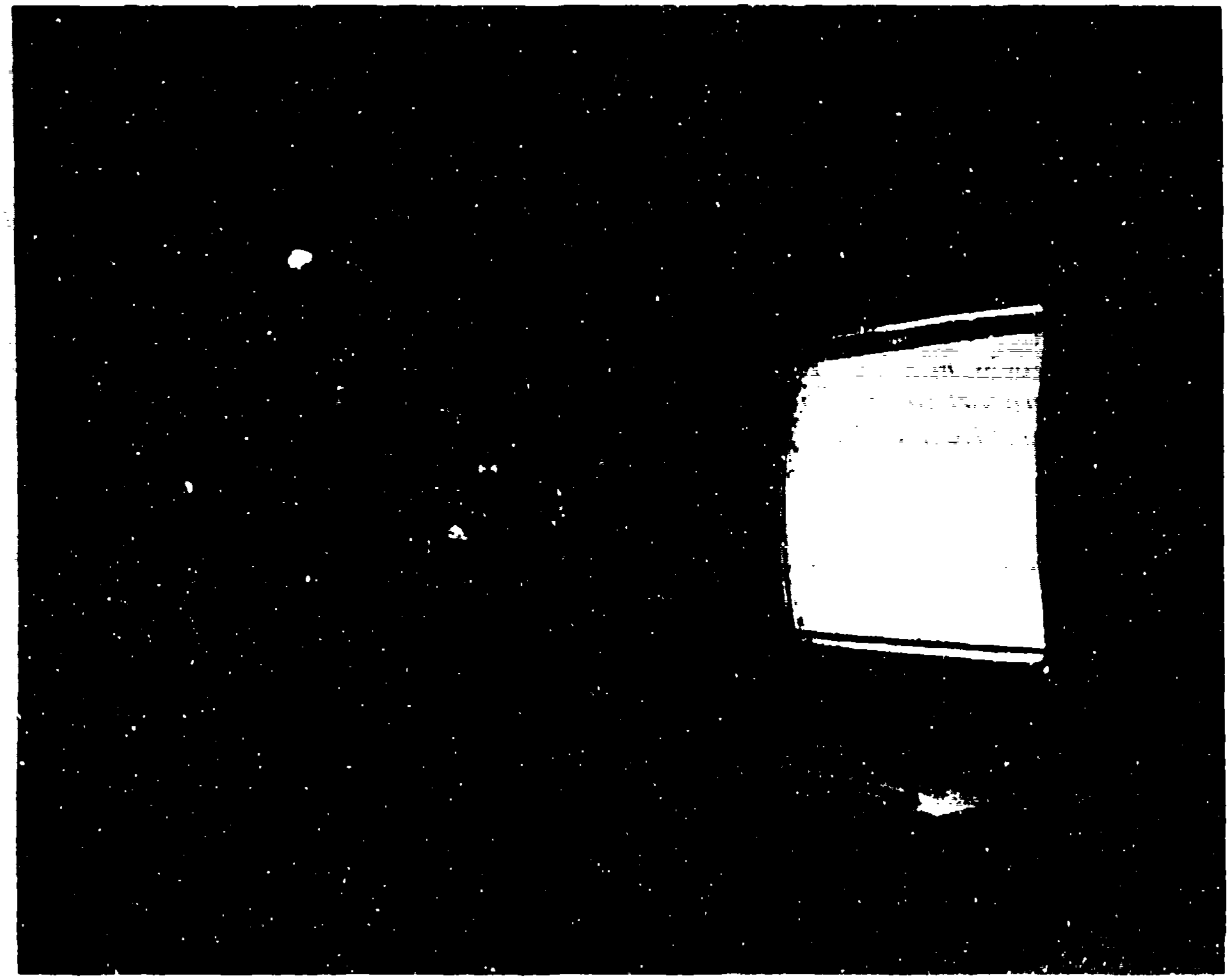
Applying new technologies in artificial intelligence and cognitive science to the development of interactive computer-based training systems can provide support in areas where the developers lack expertise. For example, the Graphics Editor developed in connection with Steamer (a training system for the instruction of steam propulsion), allows nonprogrammers to create dynamic, inspectable computer diagrams interactively. The research described here focuses on the development of Designer, an interactive visual design consultant for users of this editor. Designer will aid developers by providing graphic expertise during the construction and critiquing of Steamer diagrams. This expertise includes graphic design principles as well as standards of presentation. Designer is expected to improve the quality of the instruction by making the diagrams more consistent and visually more effective.

BACKGROUND

The development of interactive training systems and human-computer interfaces requires expertise in a number of different domains. Currently a developer needs to be knowledgeable about the substantive domain of the application as well as computer programming, instruction, and interface design. Emerging new technologies in artificial intelligence and cognitive science provide opportunities to create computer-based tools for providing support in domains outside of the developers' areas of expertise. For example, Steamer, a computer-based training system for propulsion engineering, provides a Graphics Editor that allows nonprogrammers to graphically create interactive dynamic diagrams. This facility has allowed propulsion engineering instructors to create substantial portions of this advanced training system. They have used this editor to create over 100 diagrams that serve as the students' interface to a steam plant simulation. However, users of the Steamer Graphics Editor have had difficulty maintaining drawing conventions across and even within diagrams. In addition, important graphic design principles are often violated.

OBJECTIVE

This research is being conducted to provide a mechanism for users of the Graphics Editor to maintain diagram conventions and more fully exploit techniques of good graphic design in the construction of Steamer diagrams. More generally, it is the objective of this research to explore the use of explanatory



Designer is a tool to aid in the construction of computer interfaces used in instructional training systems. It provides graphical design expertise while constructing interactive and inspectable views. The left screen presents the view while Louis Weitzman interacts with a multi-paned graphics editor window on the right.

expert systems in the design process. Designer will be an interactive visual design consultant that will incorporate generic graphic design principles and drawing standards to critique and aid in the construction of Steamer diagrams. The resulting diagrams will be visually more effective and stylistically more consistent. This system will increase the productivity of the developers while enhancing the effectiveness of the instruction.

Another goal of this project is to create a general tool for assisting the design process. By providing an independent framework for critiquing, explaining, and exploring design alternatives, the domain of the critique can be changed without affecting the structure of the critiquing mechanism itself. Even though these designs will be analyzed in the domain of the graphic arts, the same framework can be employed to provide critiques in other domains (e.g., circuit design, architectural design).

In addition to merely describing design alternatives, the system will provide a facility for exploring the design space; that is, to explain the advantages and disadvantages of the different design solutions through interactive dialogue and constructive examples, the system will tutor students in the principles of design for the given domain.

APPROACH

Designer consists of three interrelated processes, an Analyzer, a Critiquer, and a Synthesizer, coupled to a domain dependent knowledge base. This knowledge base consists of design elements and relationships, techniques for their identification, and the constraints used in distinguishing good design from bad. The Analyzer first parses the design based on the elements and relationships of the given domain. The Critiquer uses this information to indicate where the current design fails to conform to principles of good design or predetermined guidelines. Finally, based on searches of the design space, the Synthesizer process suggests alternative modifications to the current state of the design. The alternatives are explained in terms of their potential contribution to the final solution. The separation of these three processes from the knowledge base provides the desired independence and modularity of the system.

Domain-based design constraints are the basis of the critiquing process. Constraints within Designer consist of both basic graphic design principles important in the construction of two-dimensional diagrams and diagram standards that have been adopted for Steamer diagrams (e.g., format of titles and pipe width standards). The combination of principles and standards create a context or style within which the design critique and subsequent modifications take place. By modifying the style within which a critique is made, one can ultimately affect the form of the final design. It thus becomes possible under this paradigm to request multiple critiques, each based on a different style. This paradigm is especially powerful for designs that may be presented in different media, each with different constraints that need to be considered. For example, a style appropriate for a high-resolution color display on a computer screen may not be appropriate for a black and white presentation on hard copy where features are not as clearly distinguishable.

PROGRESS

An initial implementation of Designer is under development. A functioning Analyzer and Critiquer used on existing Steamer diagrams have provided useful feedback. It was very encouraging that, even in the diagrams that we had thought were carefully crafted, this early version of the system was able to note inconsistencies and suggest improvements.

Progress has been made in identifying the basic elements, relationships, and principles of two-dimensional graphic design. This knowledge has been incorporated in the construction of Designer's processes. The Analyzer first evaluates the different design elements in terms of their size, shape, color, and location and then identifies the relationships that are in the knowledge base. These relationships include similarity, proximity, grouping, and repetition. As new relationships are identified, they can easily be added into the analysis process to enhance this phase of the system. Various techniques exist to inspect interactively the elements and relationships identified within the design.

The Critiquer locates examples and violations of the design constraints provided in the current style and creates the critique comments. These critique comments include descriptions and justifications based on the graphic constraint from which they were derived. Since the critiquer works within the context of a current style, there are facilities to help define graphic constraints and maintain styles. A preliminary graphic constraint language allows the creation of new constraints, while a style editor has been developed to create, maintain, and switch between styles.

Figure 1 shows Designer's top level user interface. On the right side are four windows with commands to access diagrams: describe the current state of a diagram critique; analyze, critique, and synthesize a design; and maintain and edit styles. Status windows attached to these four panes keep track of the current diagram, the number of elements and relationships analyzed, the state of the critique, and the current style, respectively. The middle pane lists examples (+) and violations (-) of the current style's constraints with a more detailed description of one of the violations listed in the larger window pane on the left. Figure 1 also shows a pop-up menu that is available to edit the current style, New Style 1.

PLANS

Much of the current system is a framework built for exploring the research issues in a working system. This preliminary system is performing well, but, in many areas, functionality has yet to be developed or existing facilities need to be enhanced.

Expansion of the knowledge base of graphic design principles. With an expanded domain knowledge base, a more thorough and detailed analysis and critique can be provided and a larger design space of alternatives can be explored. Better techniques for parsing the diagram in terms of these principles should produce a less sensitive and more stable critique.

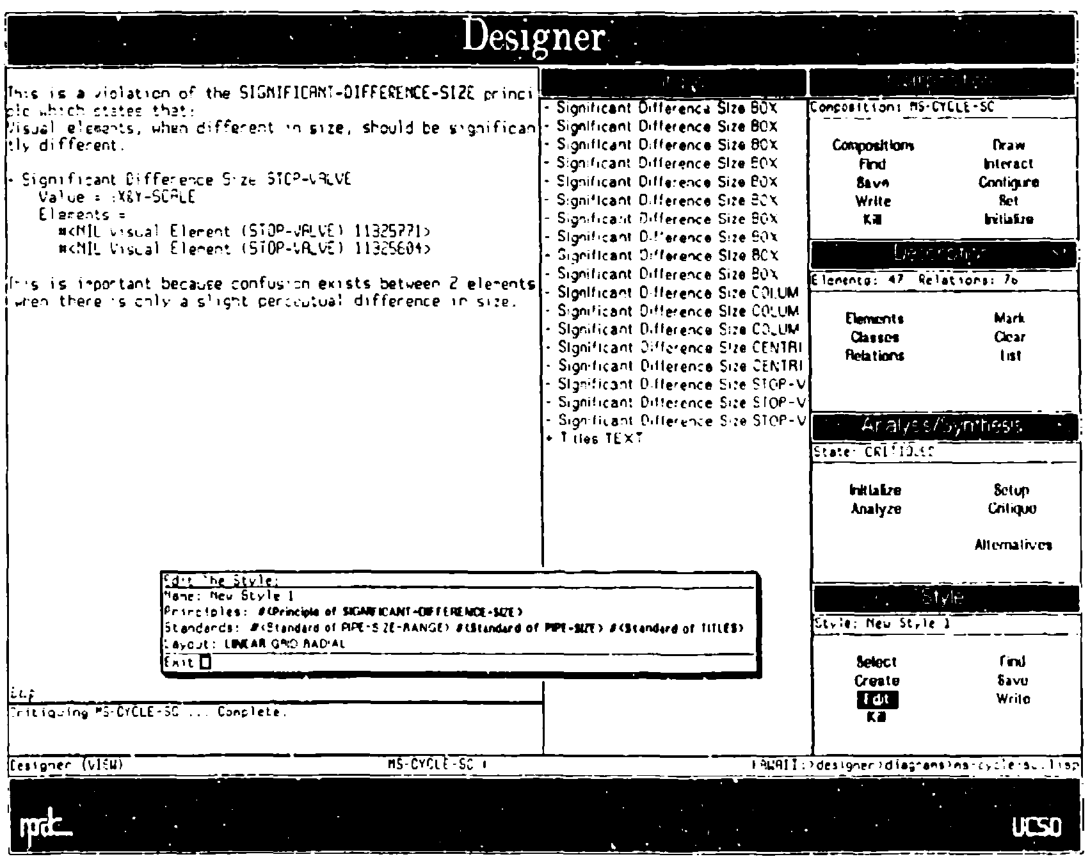


Figure 1. Designer's top level interface.

Enhancement of the explanation and description facilities. Currently the explanation facility is very limited. The system should be able to generate better explanations of the existing state. A history mechanism might also help in the description and explanation of the diagram's current state. Making the analysis, critique, and synthesis processes easier to inspect should also assist the user to improve the diagram. Only a limited number of techniques are currently employed in this area such as pointing to an element and having it describe itself, graphically indicating a design relationship, or examining a critique comment by visually marking the elements involved.

Exploration of the design space. The least developed segment of the system is exploring the design space. The existing early prototype needs much more development in order to aid the user in considering alternatives.

Creating new and enhancing existing system tools. Building tools to aid in the construction and maintenance of a system can be quite helpful. In Designer, a Style Editor manages the various styles used in the critiquing process. An enhanced Style Editor would be helpful in managing the system's existing styles, as well as in creating new ones. A Constraint Editor, built on a graphical constraint language, is planned to facilitate the construction and maintenance of new principles and standards. Another powerful tool to be incorporated in the system is a Truth Maintenance System (TMS), which maintains a set of assumptions within an environment. At this point, how to utilize a TMS within Designer has not been clearly defined, but it should be helpful in identifying contradictions within a design or explaining why it is valid.

APPENDIX A

Transitioned and Completed Independent Research/ Independent Exploratory Development Work Units

Table A-1

Independent Research Work Units for FY85 and FY86 (PE 61152N)

Work Unit		Title	Principal Investigator	Internal Code	Telephone (619) 225- or AV 933-	FY Funding ($K) 85	FY Funding ($K) 86
ZR000-01 042-04							
	.024	Models for Calibrating Multiple-choice Items	Mr. J. B. Sympson	62	6153	69[a]	40
	.025	Approaches to Multiple Objective Assignment	Dr. T. T. Liang	61	2371	0	90
ZR000-01 042-06							
	.014	Enhancing Understanding of Electric Circuits	Dr. W. E. Montague	05	7100	30	0[b]
	.025	Cognitive and Affective Processing	Dr. B. A. McDonald	51	6434	15	0[c]
	.027	Cognitive Factors in Learning and Retention	Dr. P. J. Konoske/ Dr. J. A. Ellis	72 51	2191 6434	10	0[d]
	.028	Cognitive Storage Mechanisms	Dr. M. S. Baker	52	6955	14	0[e]
	.029	Performance on Computer-based Cognitive Tasks	Dr. P-A. Federico	51	6434	0	60
	.030	Cognitive Robotics	Dr. F. R. Chang	51	6434	0	50
ZR000-01 042-08							
	.030	Positively Accelerating Sharing Rates	Dr. D. M. Nebeker	72	6935	25[f]	0[d]
	.031	Military Leadership	Dr. L. E. Atwater	04	6122	34	0[c]
	.032	Management Practices and Organizational Performance	Dr. M. C. Butler/ Dr. K. S. Crawford	72	6935	35	0[c]
ZR000-01 042-09							
	.020	Analysis of Cognition in Natural Settings	Dr. E. L. Hutchins	501	452-6771	80	50
	.027	Expert Systems for Fault Diagnosis	Dr. D. B. Malkoff	71	6617	38	0[b]
	.028	Brain Mechanisms for Human Color Vision	Dr. L. J. Trejo	71	6617	0	50
ZR000-01 042-99		To be distributed				0	32
						350	372

[a]Cost shared with Center 6.2 funding ($20K from PE 62763N).

[b]Independent Exploratory funding for FY86.

[c]Concluded.

[d]Transitioned.

[e]Terminated due to Center priorities.

[f]Cost shared with Center 6.2 funding ($50K from PE 62763N)

Table A-2

Independent Exploratory Development
Work Units for FY85 and FY86
(PE 62766N)

Work Unit	Title	Principal Investigator	Internal Code	Telephone (619) 225- or AV 933-	FY Funding ($K) 85	86
ZF66-511						
.013	Multiple Criterion Optimization Techniques	Dr. T. T. Liang	61	2371	15	0[a]
ZF66-512						
.015	Interfaces for Combat Decision Support	Dr. F. L. Greitzer	71	2081	90	0[a]
.016	Impact of Statistical Process Control	Dr. L. A. Broedling	52	6522	10	0[b]
.017	Development of Graphic Design Aids	Mr. L. M. Weitzman	501	7100	50	50
.018	Expert Systems for Fault Diagnosis	Dr. D. B. Malkoff	71	6617	0[c]	100
.019	Changes in Cognitive Structures Training[d]	Dr. W. E. Montague	05	7100	0[c]	60
					165	210

[a]Transitioned.

[b]Concluded.

[c]IR funding for FY85.

[d]Previously titled "Enhancing Understanding of Electric Circuits."

Table A-3

Independent Research and Independent Exploratory Development Work Units Completed At the End of FY85

Work Unit			Title	Reason for Termination
			Independent Research Work Units	
ZR000-01	042-06	.014	Enhancing Understanding of Electric Circuits	IED funding (see Table A-2).
		.025	Cognitive and Affective Processing	Concluded.
		.027	Cognitive Factors in Learning and Retention	Transitioned (see Table A-4).
		.028	Cognitive Storage Mechanisms	Terminated due to Center priorities.
	042-08	.030	Positively Accelerated Sharing Rates	Transitioned (see Table A-4).
		.031	Military Leadership	Concluded.
		.032	Management Practices and Organizational Performance	Concluded.
	042-09	.027	Expert Systems for Fault Diagnosis	Transitioned to IED (Table A-2).
			Independent Exploratory Development Work Units	
F66-511	ZF66-511	.013	Multiple Criterion Optimization Techniques	Transitioned (see Table A-4).
	ZF66-512	.015	Interfaces for Combat Decision Support	Transitioned (see Table A-4).
		.016	Impact of Statistical Process Control	Concluded.

Table A-4

Transitioned Independent Research and Independent Exploratory Development Work Units (FY85)

IR/IED Title	New Title	Sponsor	Program Element	FY86 Expected Funding ($K)
Independent Research Work Units				
Cognitive Factors in Learning and Retention	1. Functional Context Training	CNO (OP-01)	63720N	500
	2. Classroom Instructional Technologies	ONT	62763N	315
Positively Accelerated Sharing Rates	Improving Individual and Unit Productivity	ONT	62763N	295
Independent Exploratory Development Work Units				
Multiple Criterion Optimization Techniques	1. Career Management Planning	ONT	62763N	340
	2. Personnel Assignment Systems	CNO (OP-01)	63707N	430
Interfaces for Combat Decision Support	Decision Aiding in Combat Systems	ONT	62757N	230

Note. CNO = Chief of Naval Operations; ONT = Office of Naval Technology.

APPENDIX B

Independent Research/Independent Exploratory Development Researchers' Awards and Honors

INDEPENDENT RESEARCH/INDEPENDENT EXPLORATORY DEVELOPMENT RESEARCHERS' AWARDS AND HONORS

Atwater, L. E.

Judge at International Science and Engineering Fair, Shreveport, LA (May 1985).

Broedling, L. A.

Invited presentation on the subject of quality management to the Total Quality Control Council of Rogers Corp (March 1985).

Invited presentation on the subject of quality management to the California Society of Professional Engineers Annual Convention (June 1985).

Crawford, K. S.

Recipient of NAVPERSRANDCEN's First Annual Professional Publications Award for the most outstanding article published in a scientific journal (January 1985).

Invited presentation, "Using Gain Sharing Programs to Improve Productivity in the Federal Government," at 23rd Biennial Federal Personnel Management Conference, San Francisco (November 1984).

Received Performance Management Recognition System Award (1984-1985).

Ellis, J. A.

Member of the Editorial Board for the Journal of Educational Psychology.

Invited workshop presentation, "Instructional Quality Control and Test Development," for West Coast Shipyard Training Developers. Received a letter of commendation from the Naval Sea Systems Command.

Greitzer, F. L.

Invited presentation, "Intelligent Tactical Assistant," Technical Cooperation Panel, (July 1985).

Hutchins, E. L.

Awarded John D. and Catherine T. MacArthur Foundation Fellowship for 1985-1990.

Invited presentation, "Color Nomenclature Research," Department of Anthropology, departmental colloquium, Duke University (January 1985).

Invited presentation, "Direct Manipulation Interfaces," departmental colloquium, School of Education, University of California, Berkeley (March 1985).

Invited presentation, "Direct Manipulation Interfaces," presented at ONR Contractors Conference, University of Washington, Seattle, WA (May 1985).

Invited presentation, "Maneuvering Board Training System," Operation Specialist Advisory Board Meeting, San Diego, CA (May 1985).

Invited presentation, "Future Technologies for Training," Navy-wide Technical Review of Artificial Intelligence Research and Development, Washington, DC (September 1985).

Liang, T. T.

Received Performance Management Recognition System Award (1984-1985).

Malkoff, D. B.

Invited presentation, "Recent Progress in Introducing Artificial Intelligence Into Brain Analysis," UC San Diego School of Medicine, Department of Neurosciences, San Diego, CA (June 1985).

Invited participant at Brain Mapping Workshop, sponsored by the Army Medical Research and Development Command, Texax A&M University (August 1985).

Member of the American Academy of Neurology, American Medical EEG Association, American Association for Medical Systems and Informatics, and the Society for Neuroscience.

McDonald, B. A

Received letter of commendation from the Fleet Combat Training Center, Pacific for major contributions in the areas of electronic warfare and electronic countermeasure training over a 3-year period and for work in cognition and emotion as related to Tactical Decision Making.

Montague, W. E.

Member of Editorial Boards for the Journal of Experimental Aging Research, Educational Psychologist, Journal of Educational Psychology, American Educational Research Journal, Educational Evaluation and Policy Analysis, and Training Technology.

Proposal reviewer for Office of Naval Research and National Science Foundation.

Invited presentation, "Computer-based Training and Instructional Quality," Gould Association.

Invited presentation, "Where's the Intelligence in Intelligent CBI?", National Society for Performance and Instruction, San Diego Chapter.

Invited presentation, "Computer-based Instruction," Air Force Technology in Training and Education Conference.

Invited presentation, "Implementation of Instructional Technology," Office of Naval Research Conference.

Invited presentation, "Workshop on Intelligent Tutoring Systems," Courseware, Inc.

American Psychological Association, Divisions 21 and 14 jointly sponsored invited workshop, Applications of Technology in Training, Los Angeles, CA (August 1985).

Received letter of commendation for USMC Individual Training Standards Program Review (March 1985).

Member of Chief of Naval Education and Training committees on embedded training and rate training.

President, Human Factors Society, San Diego Chapter.

Nebeker, D. M.

Invited to press conference sponsored by Minolta, Corp. in New York, "Employee gain sharing for office professionals: Are we missing an opportunity?" (April 1985).

Member of Editorial Board of Organizational Behavior and Human Decision Processes.

Invited member of Society for Organizational Behavior, which limits itself to 60 members worldwide.

Invited presentation to Workforce Effectiveness Division Head of Office of Personnel Management regarding research at the NAVPERSRANDCEN Organizational Systems Simulation Laboratory.

Sympson, J. B.

Invited presentation, "Stochastic Modeling in Psychological Test Theory," Operations Research Department, Naval Postgraduate School, Monterey, CA (February 1985).

Invited review of Applications of Item Response Theory published in Applied Psychological Measurement Journal (Vol. 8, No. 4, pp. 467-470).

Manuscript reviewer for Psychometrika and Journal of Educational Measurement.

APPENDIX C

Independent Research/Independent Exploratory Development Presentations and Publications

INDEPENDENT RESEARCH PRESENTATIONS

Konoske, P. J., & Ellis, J. A.

Effects of Learning and Retention of Procedural Tasks. Paper presented to the American Educational Research Association, Chicago, IL (April 1985).

Malkoff, D. B.

Spoke on his IR research project, Expert Systems for Fault Diagnosis, at the U.S. Naval Academy, Naval Research Laboratory, Office of Naval Research, and Naval Sea Systems Command (April, May 1985).

Morrison, R. F.

Implications for career choice and planning. Invited address for Division 14, American Psychological Association Annual Meeting, Los Angeles (August 1985).

Sympson, J. B.

"Principal Component Analysis of Polychotomous Item Responses," and "A Family of Distribution Functions" presented at the Office of Naval Research conference on Model-based Psychological Measurement, Princeton, NJ (October 1984).

INDEPENDENT EXPLORATORY DEVELOPMENT PRESENTATIONS

Chang, F. R.

Development of computer-based writing aids. Paper presented at the annual meeting of the American Educational Research Association, Chicago, IL (April 1985).

Writing text for many readers: A role for technology. Paper presented at the international conference on The Future of Literacy in a Changing World: Synthesis From the Industrialized and Developing Nations. University of Pennsylvania, Philadelphia, PA (May 1985).

Liang, T. T.

A method to generate policy goals for the Navy's assignment problem. Presented to the 12th International Symposium on Mathematical Programming at the Massachusetts Institute of Technology, Cambridge, MA (August 1985).

INDEPENDENT RESEARCH PUBLICATIONS

Federico, P-A (1985). Cognitive complexity and cerebral sensory interaction. Personality and Individual Differences, 6(2), 253-261.

Federico, P-A (1985). Individual differences in concept learning and brain event-related potentials. Personality and Individual Differences, 6(2), 243-252.

INDEPENDENT EXPLORATORY DEVELOPMENT PUBLICATIONS

Liang, T. T., & Shao-Ju, L. (December 1985). A systems approach to integrate manpower planning and operation. Socio-Economic Planning Sciences, 19(4).

Liang, T. T, & Thompson, T. J. (In press). A large scale personnel assignment model for the Navy. Decision Sciences.

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This report provides summaries of FY85 Independent Research (IR) and Independent Exploratory Development (IED) efforts and the IR/IED funding profile, as well as IR/IED researchers' awards and honors for FY85 and presentations and publications based on IR/IED efforts.

The following IR efforts are described: models for calibrating multiple-choice items, enhancing understanding of electric circuits, cognitive and affective processing, cognitive factors in learning and retention, reward system design and performance, relationships between management practices and organizational performance, analysis of cognition in natural settings, and expert systems for fault diagnosis. The following IED efforts are described: multiple criterion optimization techniques, interfaces for combat decision support, and development of graphic design aids.

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